

# **NASA Technical Memorandum 100656**

## **DEFINITION OF COMMON SUPPORT EQUIPMENT AND SPACE STATION INTERFACE REQUIREMENTS FOR IOC MODEL TECHNOLOGY EXPERIMENTS**

**Richard A. Russell  
Richard D. Waiss**

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INTERFACE REQUIREMENTS FOR IOC MODEL  
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**Langley Research Center  
Hampton, Virginia 23665-5225**



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## Introduction

Many technology development experiments have been proposed that will be conducted while attached to the Space Station. The Space Station experiments are described in the NASA Mission Requirements Data Base (MRDB) and the technology development mission experiments are contained in the TDMX section.

In February of 1986, the Associate Administrator for Aeronautics and Space Technology (OAST) identified a group of initial operating capabilities (IOC) model technology experiments to the Acting Associate Administrator for Space Station (OSS). The purpose was to allow their requirements to be factored into the IOC Space Station Design.

A study to identify the Space Station accommodation requirements for these IOC model technology experiments was conducted. The initial activity involved updating the TDMX model experiments with each principle investigator (PI). After numerous contacts and visits with the PI's, a detailed technical understanding and a well defined experiment support equipment list was generated which included for the first time a definition of the experiment instrumentation and data requirements. The understanding and definition of these requirements resulted in the following:

- o Identification of support equipment/hardware (e.g., command/control, health status, housekeeping, etc.) requirements for each of the IOC experiments.
- o Identification of a minimal set of common support equipment/hardware to accommodate IOC experiments.
- o Preliminary definition of the pressurized laboratory interface requirements (e.g., rack space, data and storage, storage, etc.) for the IOC experiments.

Based on the results of this study, a strong case can be made for a dedicated technology experiment command and control work station consisting of a command keyboard, cathode ray tube, data storage, television monitor, computer/-processor and an alert/annunciator panel located in the pressurized laboratory.



## **OBJECTIVE**

The facing page chart identifies the overall objective for the study.



# Objective

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**Define common support equipment and**

**Space Station interface requirements**

**for IOC model technology experiments.**



## **SPECIFIC STUDY TASKS**

The total study effort was divided into five specific study tasks. These are paraphrased on the chart on the facing page.



# Specific Study Tasks

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- Identification of support equipment/hardware (command/control, health/status, housekeeping, etc.) requirements for each of the IOC experiments
- Identification of minimal set of common support equipment/hardware to accommodate the IOC experiments considering the sharing or time-phased use of the equipment/hardware
- Preliminary definition of the pressurized laboratory requirements for the common support equipment/hardware (e.g., rack space, interfaces with Space Station subsystems, weight, etc.)
- Determination of the compatibility of IOC experiments for accommodation at single external location (e.g., viewing, contamination, micro-g, etc.)
- For compatible IOC experiments, determination of the common experiment hardware that could be utilized to satisfy multiple experiment objectives



## **TDMX MODEL SET**

The facing page chart identifies the TDMX's specified for this study. Originally, this list included only 20 TDMX's. It was subsequently expanded to 21 by the addition of the Space Station Structural Performance Experiment herein identified as TDMX SPE. The support equipment and interface requirements for each of these TDMX's are defined in this report. Note that the TDMX's are grouped chronologically and technologically by NASA Centers in this chart and throughout this report.



# TDMX Model Set

<u>Number</u>	<u>Title</u>	<u>Sponsor</u>
2071	Flight Dynamics Identification	JPL
2411	Advanced Adaptive Control	JPL
2412	Distributed Control Experiment	JPL
2413	Dynamic Disturbance Experiment	JPL
2441	Microelectronics Data System Experiment	JPL
2462	Dextrous Teleoperator Technology	JPL
2461	Teleoperated Structure Assembly	JPL
2132	Advanced Radiator Concepts	LeRC
2153	Advanced Solar Dynamic Power	LeRC
2311	Long-Term Cryogenic Fluid Storage	LeRC
2011	Spacecraft Materials and Coatings	LaRC
2072	Spacecraft Strain and Acoustics Sensors	LaRC
SPE	Space Station Structural Performance Experiment	LaRC
2442	Transient Upset Phenomena in VLSI Devices	LaRC
2443	VHSIC Fault Tolerant Processor	LaRC
2561	Satellite Servicing and Refurbishment	MSFC
2562	Satellite Maintenance and Repair	MSFC
2572	Cryogenic Propellant Transfer/Storage/Reliquification	MSFC
2573	OTV Docking and Berthing	MSFC
2574	OTV Maintenance Technology	MSFC
2571	OTV/Payload Interfacing and Transfer	MSFC

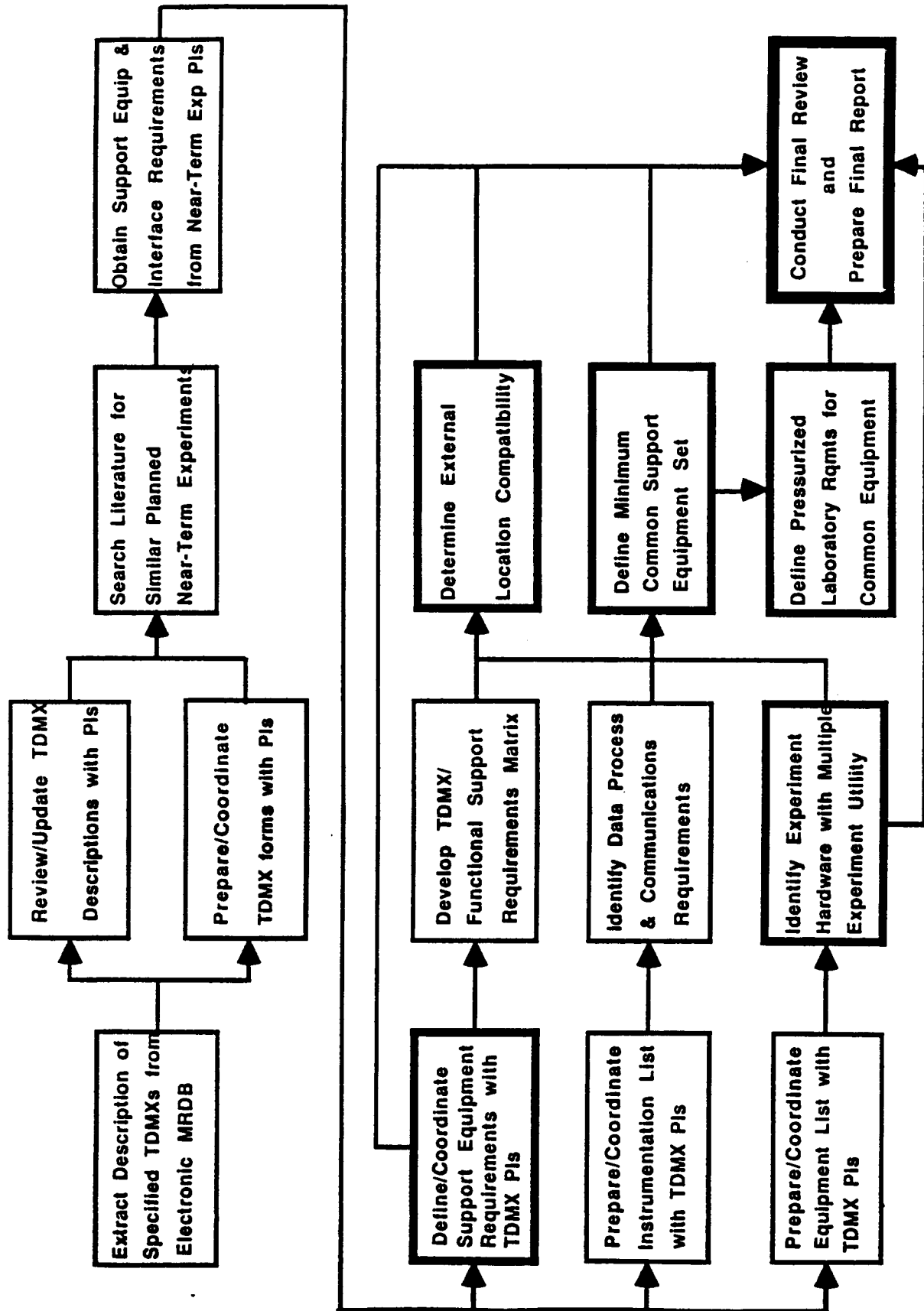


## **TASK METHODOLOGY**

At the outset of this study, a task methodology was developed to have a "road map" to follow. The chart on the facing page shows this methodology. A review of this methodology reveals that the TDMX principal investigators (PIs) were consulted frequently during this effort. Note also that each of the five specific study tasks are identified as well as the final review and report are highlighted.



# Task Methodology





## **CREW SUPPORT STATION EQUIPMENT**

The chart on the facing page partially addresses the request for a "preliminary definition of the pressurized laboratory requirements for the common support equipment/hardware (e.g., rack space, interfaces with Space Station subsystems, weight, etc.)". Specifically, it identifies the laboratory equipment/resources required to support the given TDMX model set. An examination of this chart shows that most of the experiments need the control/services generally associated with a high technology laboratory control center (i.e., a work station that interfaces with the experiments through a computer and associated ancillary hardware).

Based on the data given on this chart and the detailed data processing and storage requirements, a strong case can be made for a dedicated TDMX work station with a command keyboard, cathode ray tube, and an alert/annunciator panel in the pressurized laboratory.



# Crew Support Station Equipment

TDMX	Command	Keyboard	Cathode Ray Tube	Computer/Processor	Internal Storage	Data Storage	Alert Panel	Television Monitor	Teleoperator Work Station	Docking/Berthing Cntrl Cntr	Mobile Service Center	Dedicated Rack Space			
2071	X		X	X		X		X			X	X			
2411	X		X	X		X		X				X			
2412	X		X	X		X		X				X			
2413	X		X	X		X		X			X	X			
2441				X		X		X	X		X				
2462				X		X		X	X		X	X			
2461				X		X		X	X		X	X			
2132	X		X	X		X	X	X			X	X			
2153	X		X	X		X	X				X				
2311	X		X	X		X	X				X				
2011	X		X	X		X					X	X			
2072	X		X	X		X	X								
SPE	X		X	X		X	X								
2442	X		X		X	X	X					X			
2443	X		X		X	X						X			
2561	X		X	X	X	X	X	X			X				
2562	X		X	X	X	X	X	X			X				
2572	X		X	X	X	X	X	X			X	X			
2573	X		X	X		X	X	X			X	X			
2574	X		X	X	X	X	X	X			X	X			
2571	X		X	X	X	X	X	X			X	X			



## EXTERNAL LOCATION COMPATIBILITY

The study asked for a "determination of the compatibility of the IOC experiments for accommodation at a single external location (e.g., viewing, contamination, micro-g environment, etc)." The facing page chart addresses this request. It identifies location related characteristics/requirements of the given TDMX set. A review of this chart reveals that about half of the experiment (TDMX's 2011, 2071, 2153, 2411, 2412, 2413, and 2441) can be located on the upper boom. Because they require solar pointing, two of these experiments (TDMU's 2011 and 2153) will have to be mounted on the end of the boom.

The upper boom is not considered a suitable location for the remaining experiments because they have to be within eyesight of the mobile service center work station (TDMX's 2461 and 2462), are potential contaminant producers (TDMX's 2132, 2561, 2562, 2571, 2572, 2573, and 2574), are intentionally distributed to perform their function (TDMX's 2072 and SPE), or are located by their very nature in one of the pressurized modules (TDMX's 2442 and 2443).



# External Location Compatability

TDMX	Induces Disturbances	Contaminant Producing	Solar Pointing	Solar Avoidance	Wake Facing	Velocity Facing	External Storage	Mobile Service Center	Docking/Berthing Required	PPS Required	SIA/PIA Compatible			
2071				X				X			X			
2411				X							X			
2412				X							X			
2413	X			X				X			X			
2441								X			X			
2462								X			X			
2461							X	X			X			
2132		X		X			X	X		X	X			
2153			X				X	X		X	X			
2311							X	X						
2011			X		X	X	X	X		X	X			
2072														
SPE														
2442														
2443														
2561	X	X					X	X	X					
2562	X	X					X	X	X					
2572	X	X					X	X	X					
2573	X	X					X	X	X					
2574	X	X					X	X	X					
2571	X	X					X	X	X					

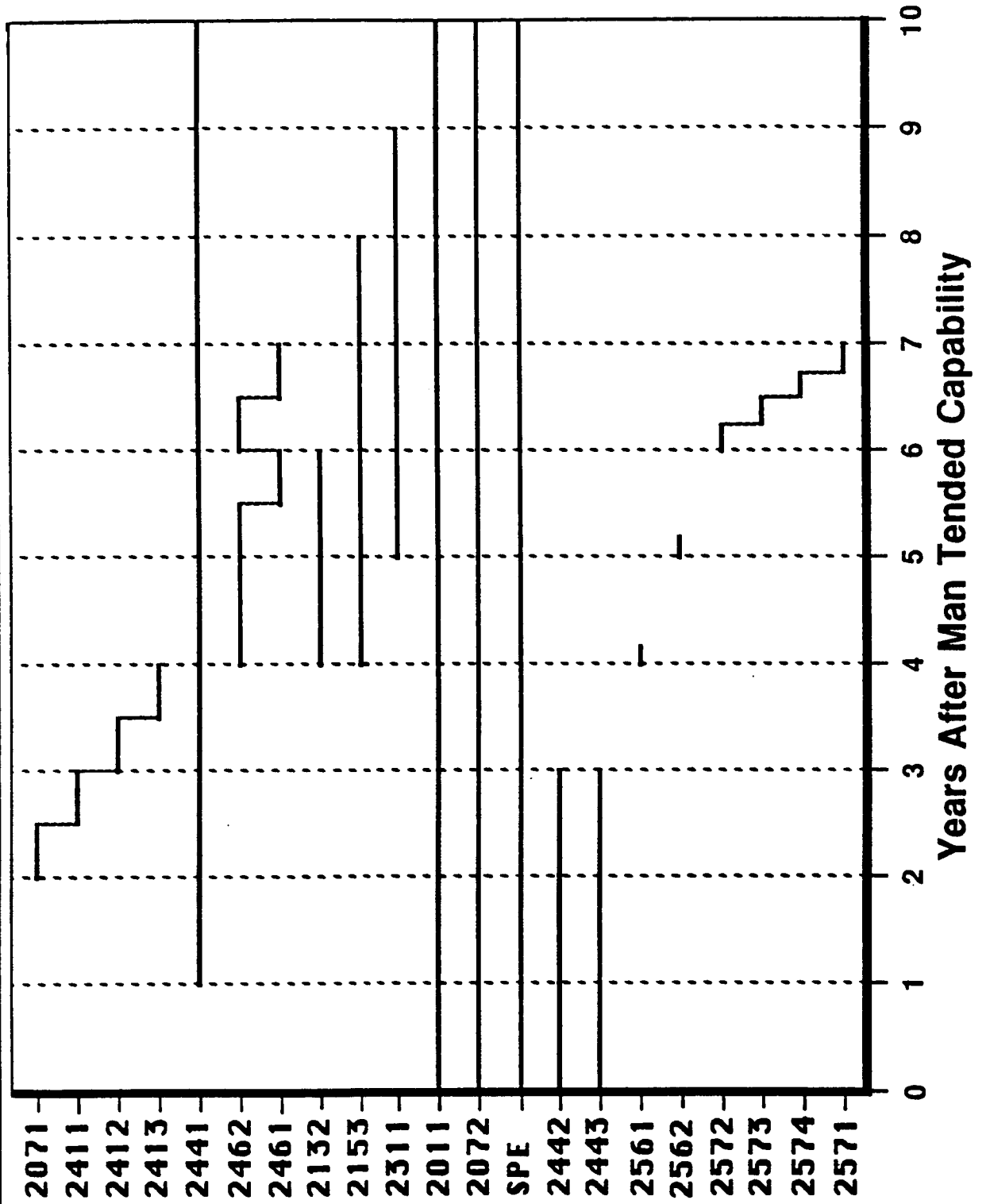


## **TDMX OPERATIONAL SCHEDULE**

Time phasing of the TDMX model set specified for this study is shown on the facing page chart. It appears realistic when compared to the base line launch schedule for the Space Station. This phasing may be employed to develop equipment/hardware sharing scenarios to accommodate the identified experiments. It was used during this study to develop an estimate of the operational IVA requirements and the electrical power requirements necessary to support these experiments.



# TDMX Operational Schedule





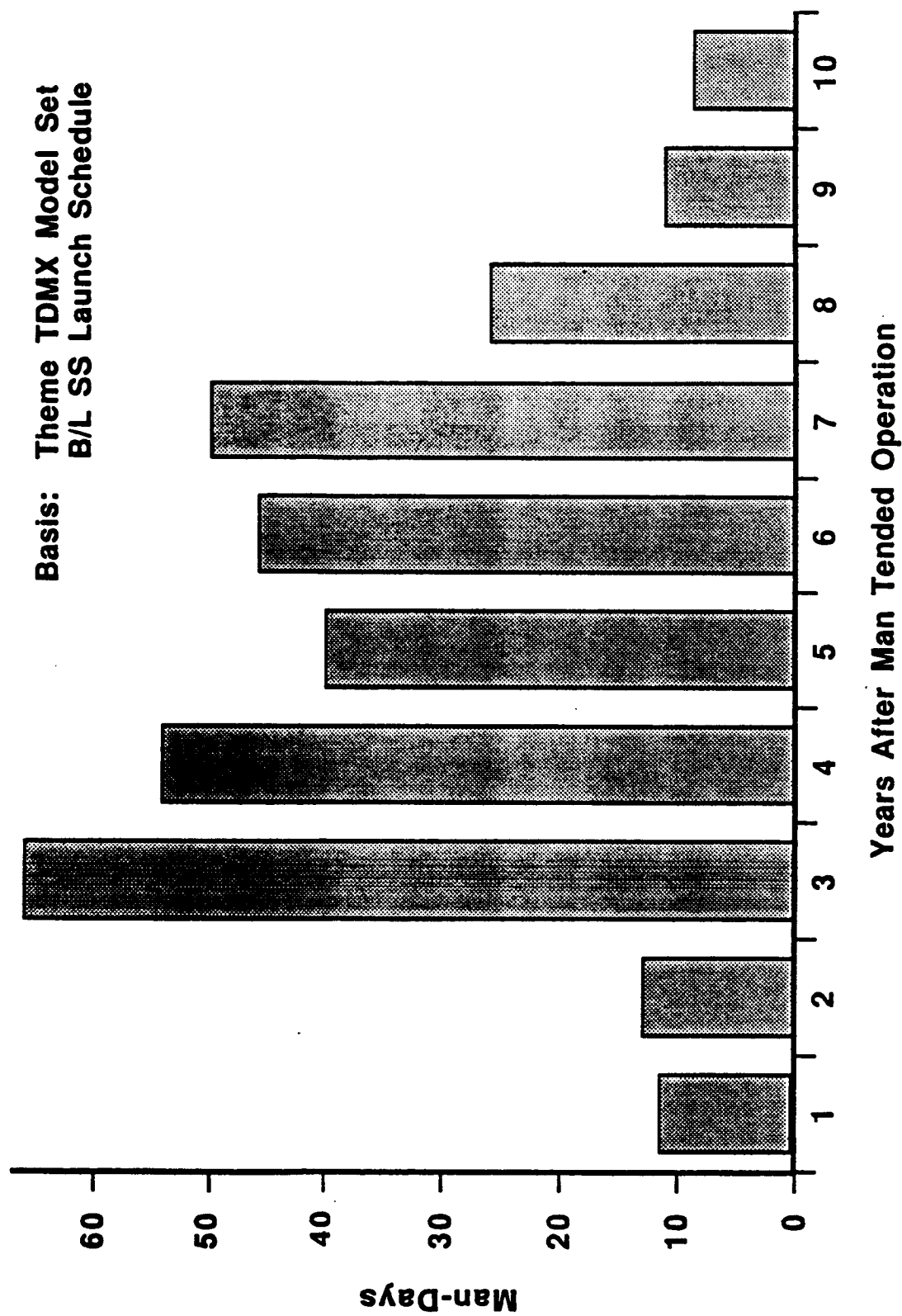
## **IVA OPERATIONAL REQUIREMENTS**

The facing page chart shows the IVA needed to support day to day operations of the given IOC TDMX set. It does not show the IVA needed to support installation, reconfiguration, or teardown activities. This chart was developed using the TDMX operational schedule shown previously. The 66 man-days needed during the third year should be easily accommodated by the crew of eight scheduled to be aboard the Space Station at this time.



# IVA Operational Requirements

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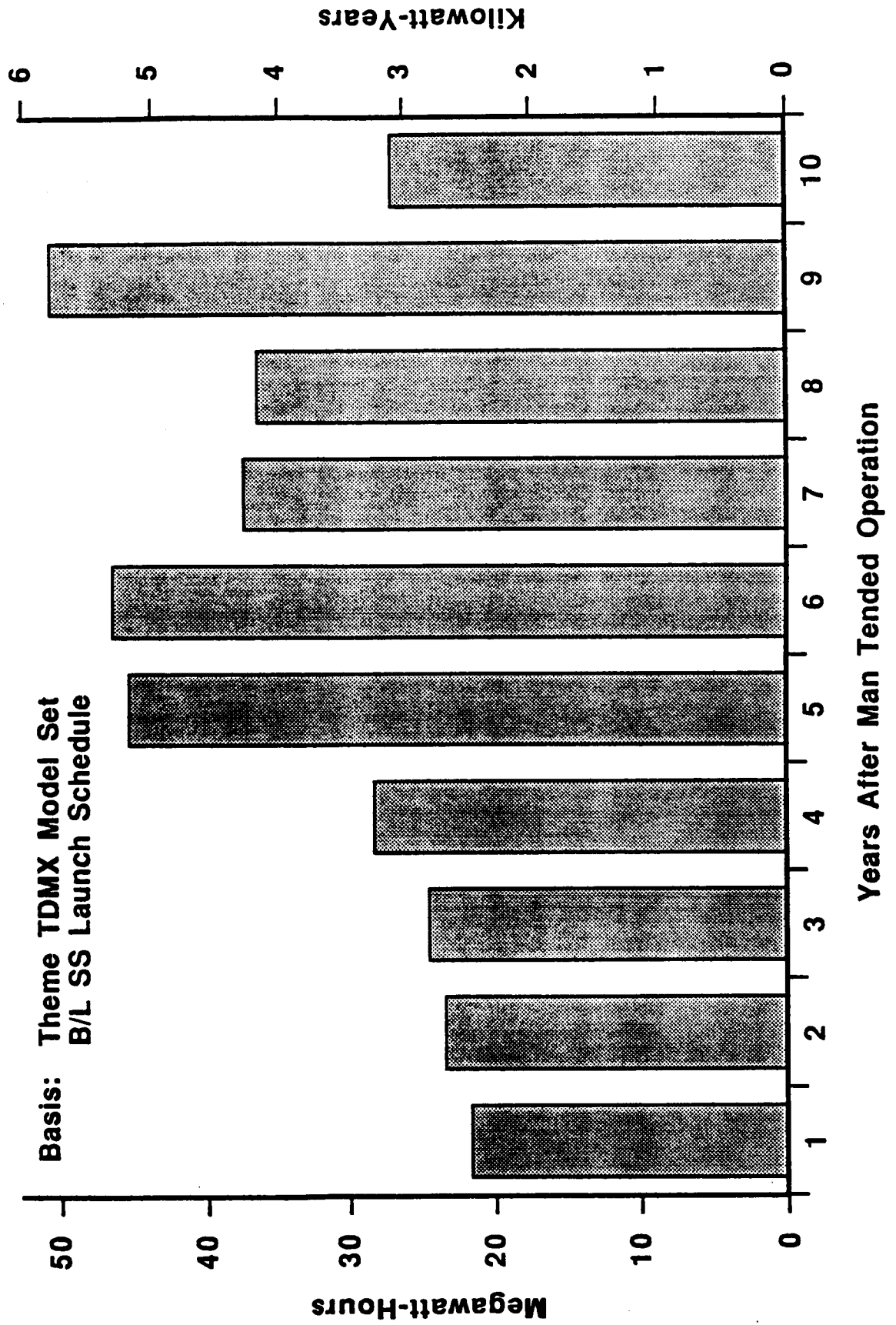


## **TDMX POWER REQUIREMENTS**

The electrical power required by the TDMX model set specified for this study is shown on the chart on the facing page. This chart is based on the TDMX operational schedule previously presented. It was developed by summing the watt-hour requirements of the individual experiments and shows that through proper time-phasing the Space Station should easily accommodate these experiments. The peak power usage occurring in the ninth year is due to 2.7 kw draw of the cryogenic refrigerator of TDMX 2311 coming on line.



# TDMX Power Requirements





## **SPACE STATION FACILITIES/SERVICES**

These charts contain a summary of the detailed TDMX Space Station resource requirements. The detailed TDMX information presented is an update and expansion of the data currently available in the Mission Requirements Data Base (MRDB). Hopefully, it will be beneficial to the various principle investigators when they update the input for their experiments in the MRDB as well as to the Space Station designers and planners who will be developing the hardware and scenarios which will accommodate these experiments.



# Space Station Facilities/Services

TDMX	ATTACHMENT INFORMATION						EVA			IVA		
	POINTING/ ORIENTATION	APAE COMPATIBLE	PREFERRED LOCATION	VOLUME MxMxM	MASS, Kg	SET-UP, SORTIES	OPERATION SORTIES/DAY	OTHER, SORTIES	SET-UP, MHRS	OPERATION MHRS/DAY	OTHER, MHRS	
2071	SOLAR AVOIDANCE	YES	NONE	15X15X20	150	2	0	4	17	7	44	
2411	" "	YES	NONE	SAME AS 2071	30	0.75	0	2	4.5	7	20	
2412	" "	YES	NONE	" "	0	0.5	0	2	3	7	20	
2413	" " ANTI- EARTH	YES	NONE	TBD	TBD	0.5	0	4	3	5	37	
2441		YES	UPPER BOOM	2X1X0.5	200	0	0	4.5	3	0	38	
2462	ANY	NO	VIEWABLE FROM HABITAT MODULE	2X3X2	1800	0.5	0.5 EVERY 15 DAYS	1.5	7	6 + 5 HRS EVERY 15 DAYS	21	
2461	ANY	YES	" "	15X8X5	TBD	2	0	1.25	22	9	16.5	



# Space Station Facilities/Services (Continued)

TDMX	MSC SUPPORT			POWER				THERMAL		TELEOPERATOR SUPPORT	CLOSED CIRCUIT TELEVISION
	SET-UP, HRS	OPERATION, HRS/DAY	OTHER, HRS	OPERATION		PEAK		ACTIVE KW	PASSIVE, KW		
				KW	HRS/DAY	KW	HRS/DAY				
2071	4	0	0	0.7	5	N/A	N/A	0.5	0.7	NO	YES
2411	0	0	0	1.4	5	N/A	N/A	0	1.4	NO	YES
2412	0	0	0	1.4	5	N/A	N/A	0	1.4	NO	YES
2413	0	0	4	1.4	4.8	4.9	0.2	0	4.9	NO	YES
2441	3	0	38	0.2	23.9	1	0.1	0.2	0	NO	YES
2462	2	3+2 EVERY 15 DAYS	6	2.4	2.9	2.8	0.1	0.6	0.6	YES	YES
2461	5	4.5	3	2	9	N/A	N/A	0.3	0.7	YES	YES



# Space Station Facilities/Services (Continued)

TDMX	DATA MANAGEMENT & EXPERIMENT CONTROL									EQUIPMENT STORAGE MXMXM	DEDICATED RACK SPACE MXMXM
	UPLINK	DOWNLINK	STORAGE MBITS	DATA RATE, KBPS	CMD CNTR		EXP DUTY CYCLE				
					GROUND	SPACE STATION	HRS/DAY	DAYS/YR			
2071	DATA	DATA	142	2 UP/ 5 DWN	YES	YES	5	90	6X3X3	1X1X1	
2411	DATA	DATA	142	2 UP/10 DWN	YES	YES	5	90	SMALL FOR ACTUATORS & SENSORS	1X1X1	
2412	DATA	DATA	142	2UP/10 DWN	YES	YES	5	90	0	1X1X1	
2413	DATA	DATA	170	2UP/10 DWN	YES	YES	5	90	TBD	1X1X1	
2441	DATA	DATA	1	10UP/11000 DWN	YES	NO	21	365	2X1X0.5	0	
2462	DATA	DATA	650	10UP/90 DWN	NO	YES	3	18	3X4X3.5	1X1X1.5	
2461	DATA	VIDEO	600	10UP/22000 DWN	NO	YES	9	21	15X8X5	1X1X1.5	



# Space Station Facilities/Services (Continued)

	ATTACHMENT INFORMATION							EVA			IVA		
	POINTING/ ORIENTATION	APAE COMPATIBLE	PREFERRED LOCATION	VOLUME M×M×M	MASS, Kg	SET-UP, SORTIES	OPERATION SORTIES/DAY	OTHER, SORTIES	SET-UP, MHRS	OPERATION MHRS/DAY	OTHER, MHRS	TDMX	
2132	SOLAR AVOIDANCE	YES	KEEL	5X2X2.5	180	1	0	3	8	0.5	24		
2153	SOLAR	YES	UPPER BOOM	15.3X9X12	1240	8	0	18	64	1	144		
2311	ANY	YES	LOWER BOOM	6.5X5.5X3.2	3175	1	0	3	20	1/WK	28		



## Space Station Facilities/Services (Continued)

TDMX	MSC SUPPORT			POWER				THERMAL		TELEOPERATOR SUPPORT	CLOSED CIRCUIT TELEVISION
	SET-UP, HRS	OPERATION, HRS/DAY	OTHER, HRS	OPERATION		PEAK		ACTIVE KW	PASSIVE, KW		
				KW	HRS/DAY	KW	HRS/DAY				
2132	4	0	12	0.7	22	5.2	2	0	5.2	NO	YES
2153	32	0	72	1	24	N/A	N/A	0	80	NO	NO
2311	4	0	12	2.7	24	N/A	N/A	2.5	0	NO	NO



# Space Station Facilities/Services (Continued)

TDMX	DATA MANAGEMENT & EXPERIMENT CONTROL									
	UPLINK	DOWNLINK	STORAGE MBITS	DATA RATE, KBPS	CMD CNTR		EXP DUTY CYCLE		EQUIPMENT STORAGE MXMXM	DEDICATED RACK SPACE MXMXM
					GROUND	SPACE STATION	HRS/DAY	DAYS/YR		
2132	CMD	DATA	1	1 UP/ 4 DWN	YES	YES	24	350	2.5X1X1	0
2153	CMD	DATA	1	1 UP/ 4 DWN	YES	YES	24	350	12X4X4	0
2311	CMD	DATA	2	1	YES	YES	24	365	5X2.5X3.5	0



# Space Station Facilities/Services (Continued)

	ATTACHMENT INFORMATION							EVA			IVA		
	POINTING/ ORIENTATION	APAE COMPATIBLE	PREFERRED LOCATION	VOLUME MxMxM	MASS, Kg	SET-UP, SORTIES	OPERATION SORTIES/DAY	OTHER, SORTIES	SET-UP, MHR	OPERATION MHR/DAY	OTHER, MHR	TDMX	
2011	A) VELOCITY B) WAKE C) SUN	YES	UPPER BOOM	10X0.2X1 5X0.2X1 5X0.2X1	110 55 55	1	4/YR	1	8	32/YR	8		
2072	ANY	N/A	PRESS MODULE	--	50	0	0	0	1	0	0		
SSPE	ANY	N/A	COMPLETE SPACE STA	--	280	0	0	TBD (NDE)	1	TBD	TBD (NDE)		
2442	ANY	N/A	PRESS MODULE	1X0.5X0.3	75	0	0	0	1	12/YR	1		
2443	ANY	N/A	PRESS MODULE	1X0.5X0.3	75	0	0	0	1	12/YR	1		



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## Space Station Facilities/Services (Continued)

TDMX	MSC SUPPORT			POWER					THERMAL		TELEOPERATOR SUPPORT	CLOSED CIRCUIT TELEVISION
	SET-UP, HRS	OPERATION, HRS/DAY	OTHER, HRS	OPERATION		PEAK		ACTIVE KW	PASSIVE, KW			
				KW	HRS/DAY	KW	HRS/DAY					
2011	4	0	4	0.46	23	0.65	1	0	0.65	NO	NO	
2072	0	0	0	0.2	23	0.4	1	0	0.4	NO	NO	
SSPE	0	TBD (NDE)	0	2.2	24	N/A	N/A	0.2	2	NO	NO	
2442	0	0	0	0.1	24	N/A	N/A	0.1	0	NO	NO	
2443	0	0	0	0.3	24	N/A	N/A	0.3	0	NO	NO	



# Space Station Facilities/Services (Continued)

TDMX	ATTACHMENT INFORMATION					EVA			IVA		
	POINTING/ ORIENTATION	APAE COMPATIBLE	PREFERRED LOCATION	VOLUME MxMxM	MASS, Kg	SET-UP, SORTIES	OPERATION SORTIES/DAY	OTHER, SORTIES	SET-UP, MHRS	OPERATION MHRS/DAY	OTHER, MHRS
2561	ANY	NO	NEAR SATSER FAC.	9X22X4.5	2250	0	1	0	3	12	2
2562	ANY	NO	" "	" "	TBD	0	1	0	3	20	2
2572	ANY	NO	NEAROTV FAC	4.5X4.5X 8.6	2700	1	0	0	16	8	2
2573	ANY	NO	" "	4.5X4.5X 8.6	2100	1	0	0	16	16	4
2574	ANY	NO	" "	10.1X10.1 X10.0	1700	4	1.5	0	28	13	0
2571	ANY	NO	" "	4.5X4.5 X4.5	0	0	1.5	4	3	18.5	48



# Space Station Facilities/Services (Continued)

TDMX	MSC SUPPORT			POWER				THERMAL		TELEOPERATOR SUPPORT	CLOSED CIRCUIT TELEVISION
	SET-UP, HRS	OPERATION, HRS/DAY	OTHER, HRS	OPERATION		PEAK		ACTIVE KW	PASSIVE, KW		
				KW	HRS/DAY	KW	HRS/DAY				
2561	0	2	0	2.5	24	3	0.5	0	2.0	NO	YES
2562	0	2	0	2.5	8	3	0.5	0	0.4	NO	YES
2572	4	0	0	1.5	24	TBD	TBD	0	1.5	NO	YES
2573	4	4	1	0.5	6	TBD	TBD	0.5	0	NO	YES
2574	4	4	0	1.6	6	TBD	TBD	1.6	0	NO	YES
2571	3	3	16	0.4	6	TBD	TBD	0	0.4	NO	YES



# Space Station Facilities/Services (Continued)

TDMX	DATA MANAGEMENT & EXPERIMENT CONTROL										EQUIPMENT STORAGE MXMXM	DEDICATED RACK SPACE MXMXM
	UPLINK	DOWNLINK	STORAGE MBITS	DATA RATE, KBPS	CMD CNTR		EXP DUTY CYCLE					
					GROUND	SPACE STATION	HRS/DAY	DAYS/YR				
2561	CMD	DATA	2	2.0	YES	YES	8	TBD	TBD	0		
2562	CMD	DATA	2	2.0	YES	YES	8	TBD	TBD	0		
2572	CMD	DATA	7	12.0	YES	YES	24	365	200M <sup>3</sup>	1X0.5X1		
2573	CMD	DATA	4500	150	YES	YES	8	6	400M <sup>3</sup>	1X0.5X1		
2574	CMD	DATA	2400	52	YES	YES	8	30	1000M <sup>3</sup>	1X0.5X1		
2571	CMD	DATA	2	52	YES	YES	8	6	TBD	1X1X2		



# **Jet Propulsion Laboratory**

## **Proposed**

### **Technology Development**

#### **Mission Experiments**



## TDMX 2071

### FLIGHT DYNAMICS IDENTIFICATION EXPERIMENT CONCEPT

- **OBJECTIVE**

To determine the dynamics characteristics of large structural systems for use in orbital operations and to validate sensing strategy/mechanization, identification algorithm and integration flight control dynamics reconstruction subsystem.

- **DESCRIPTION**

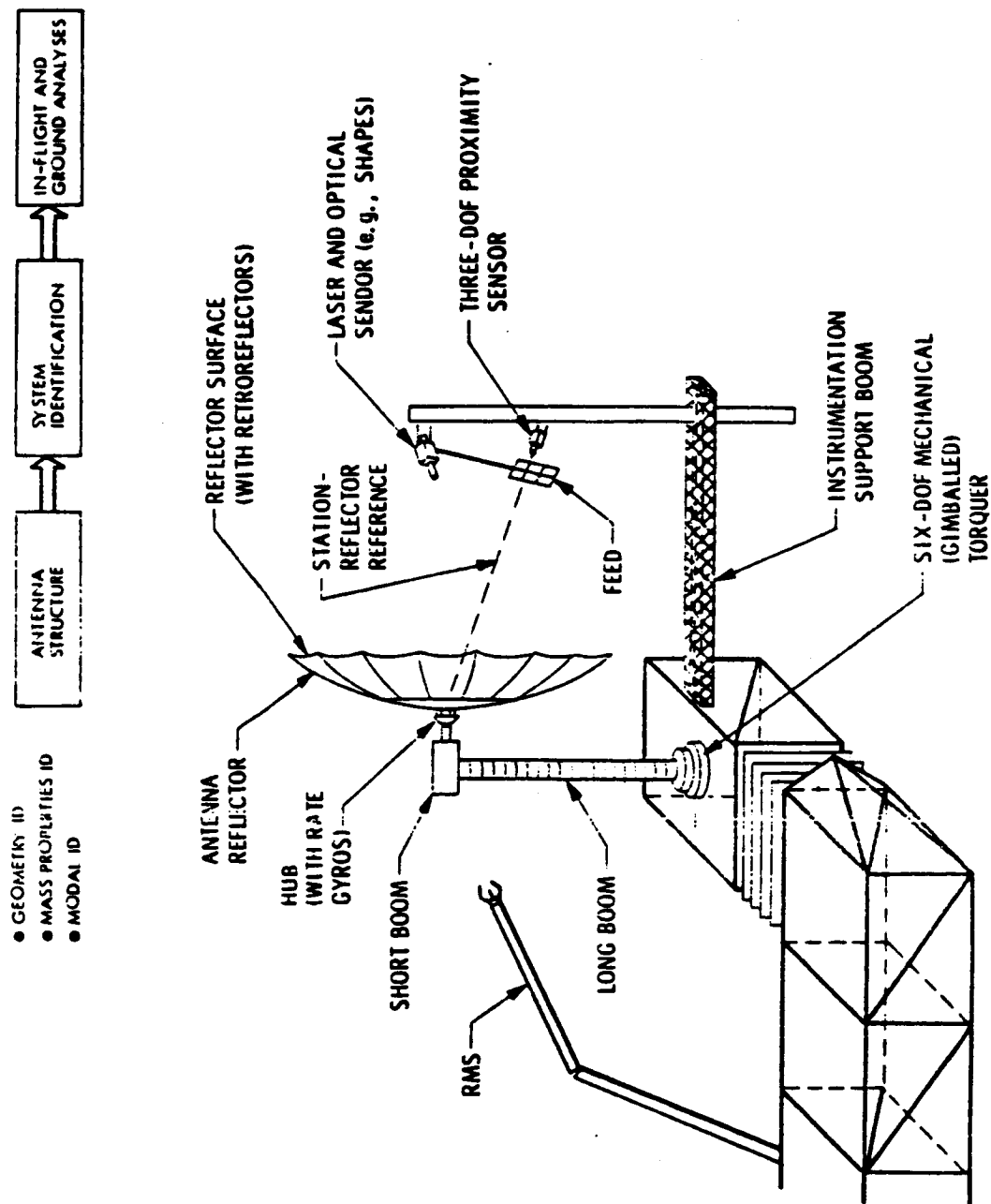
This experiment will consist of distribution excitation and sensing of structure and payloads. Sensor outputs will be recorded for off-line system identification or processed sequentially for on-board identification. The dynamics stiffness and damping characteristics of structures such as antenna dishes and manipulator systems will be measured. TDMX 2071, which is depicted on the facing page, will be continued as a subset of TDMX 2411, 2412, and 2413.



# TDMX 2071

## FLIGHT DYNAMICS IDENTIFICATION EXPERIMENT CONCEPT

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## TDMX 2071 (FDI) EQUIPMENT LIST

The list on the facing page gives an initial identification of the equipment associated with the FDI experiment.

The mission equipment used for this experiment can be categorized into external and internal equipment. The external equipment refers essentially to an antenna structure, and is inclusive of force-torque sensors and retroreflectors placed on it, as well as the mechanical torquing device on which it is mounted. The internal equipment consists of data processors, closed circuit televisions (CCTVs), special displays, sensor monitors, cathode ray tubes (CRTs), and data recorders designed for this mission, and will be primarily located on mission racks in the pressurized laboratory module during experimentation.



# TDMX 2071 (FDI) EQUIPMENT LIST

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EXTERNAL EQUIPMENT	INTERNAL EQUIPMENT
• Antenna reflector	• Rack mounted mission data instruments
• Rate gyros at antenna hub	• Data processor (capability equivalent to 1 hr. of VAX 117780)
• Mechanical torquer	• Multifunction keyboard
• Short boom	• Data recorder (142 MBITS capacity)
• Long boom	• Display for monitoring sensors and
• Instrumentation support boom	• Closed circuit TV display via CRT
• Laser and optical sensor unit	
• Retro reflector targets	



## TDMX 2071 (FDI) INSTRUMENTATION LIST

The list on the facing page provides an initial estimate of the types and numbers of instrumentation associated with TDMX 2071.

The laser measurement device, which consists of the laser source and optical sensor, should be capable of processing reflected light signals from the targets at a minimum rate of 12 samples/s because the predicted modal frequency band is given as 0.5 to 6 Hz. Current technological progress has enabled most of the modes in the specified region to be measured. However, present devices, e.g., JPL SHAPES, can attain a processing rate of only around 10 samples/s. This constraint will result in the inability to detect the entire band of modal frequencies; although present day state-of-the-art technology will capture still most of the modes of interest.



## TDMX 2071 (FDI) INSTRUMENTATION LIST

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HUB RATE GYRO PICK-OFFS 3

### ACCELEROMETERS

SHORT BOOM 9

LONG BOOM 15

INSTRUMENT SUPPORT BOOM 15

39

### ANGULAR POSITION PICK-OFFS

PROXIMITY SENSOR 3

LASER SENDER 3

BOOM CONTROLLER 3

SAMPLING RATE 10/SEC



## TDMX 2411

### ADVANCED ADAPTIVE CONTROL EXPERIMENT CONCEPT

- **OBJECTIVE**

To develop and evaluate performance and stability improvement sensing strategies and mechanization, control gain update subroutine and reconfiguration schemes, and adaptive control algorithms.

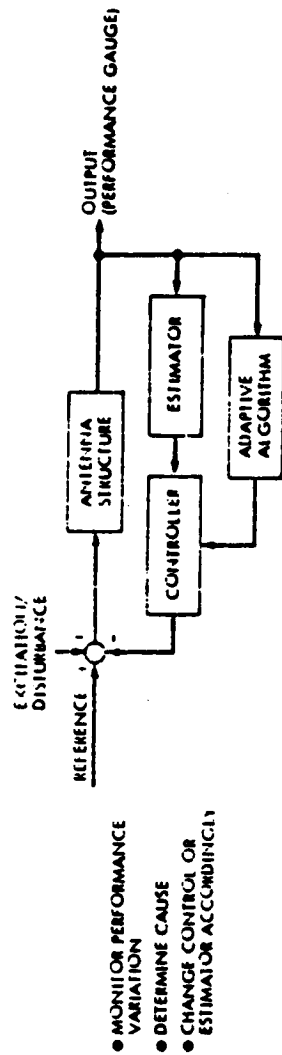
- **DESCRIPTION**

This experiment will evaluate adaptive control algorithms and measurement hierarchy for an evolving or deployed structure. It will include articulation and reconfiguration of payloads to change system mass properties and evaluate adaptive control designs. TDMX 2411, illustrated on the facing chart, will utilize the equipment from TDMX 2071. TDMX 2411 will be continued as a subset of TDMX 2412 and TDMX 2413.

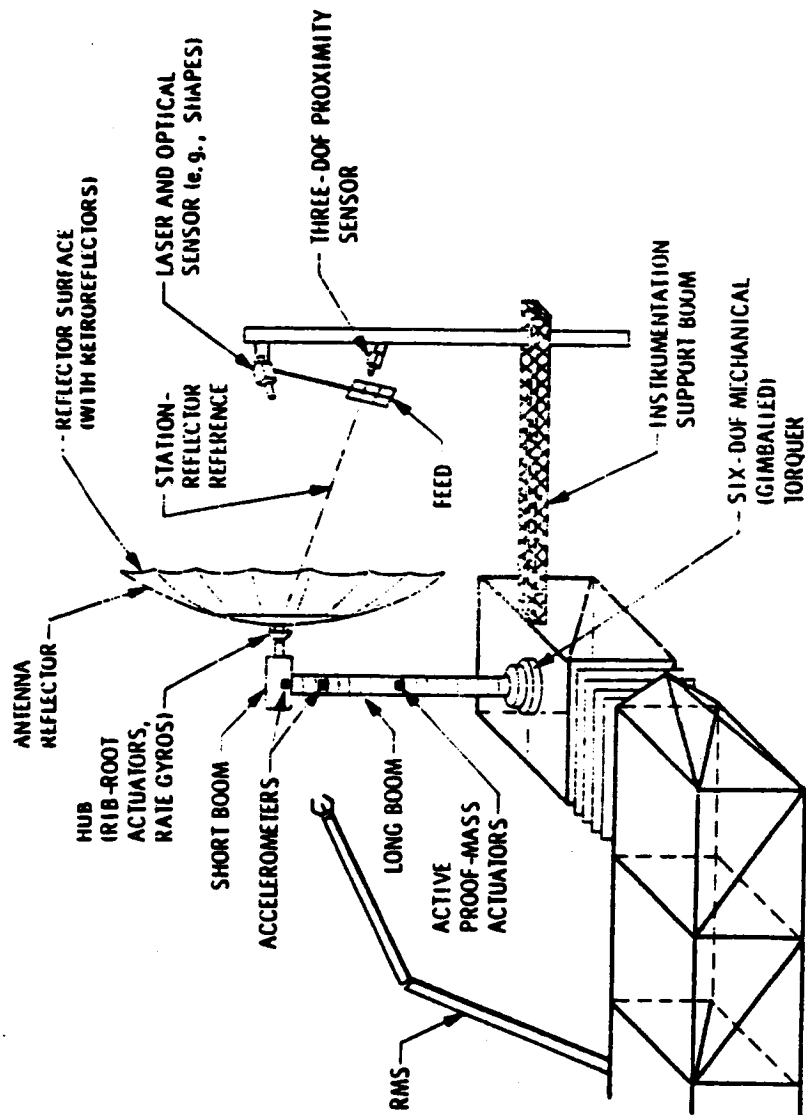


TDMX 2411

# ADVANCED ADAPTIVE CONTROL EXPERIMENT CONCEPT



ORIGINAL PAGE IS  
OF POOR QUALITY





## TDMX 2411 (AAC) EQUIPMENT LIST

The list on the facing page gives an initial identification of the equipment associated with the AAC experiment.

The mission equipment used for this experiment can be categorized into external and internal equipment. The external equipment refers essentially to an antenna structure from TDMX 2071, and is inclusive of force-torque sensors and retroreflectors placed on it, as well as the mechanical torquing device on which it is mounted. The internal equipment consists of the TDMX 2071 data processors, closed circuit televisions (CCTVs), special displays, sensor monitors, cathode ray tubes (CRTs), and data recorders designed for this mission, and will be primarily located on mission racks in the pressurized laboratory module during experimentation.

For control purposes, rib-root actuators will be added to the TDMX 2071 equipment at the reflector hub, whereas, active proof-mass actuators will be added along the long and short booms. The experiment will study the control capability of available actuators for damping control, hub orientation control, and line-of-sight pointing control. Strain gages and boom mounted accelerometers will be added for this TDMX to provide control system feedback measurements.

The adaptive control algorithms will reside in control software packages in the mission computers employed for this experiment. Because algorithm size and complexity may be considerable, usage of the Space Station computer, for certain experiments, may be necessary.



# TDMX 2411 (AAC) EQUIPMENT LIST

---

EXTERNAL EQUIPMENT	INTERNAL EQUIPMENT
• Antenna reflector	• Rack mounted mission data instruments
• Rate gyros at antenna hub	• Data Processor (capability equivalent to 1 hr of VAX 11780 each operational day)
• Mechanical torquer	
• Short boom	• Multifunction keyboard
• Long boom	
• Instrumentation support boom	• Data Recorder (142 MBITS capacity)
• Laser and optical sensor unit	• Display for monitoring sensor and digital data
• Retro reflector targets	
• Active proof-mass actuators *	
• Strain gages *	
• Rib-root actuators*	
• Boom mounted accelerometers	



## TDMX 2411 (AAC) INSTRUMENTATION LIST

The chart on the facing page presents an initial listing of the types and numbers of instrumentation sensing that is currently estimated for TDMX 2411.

Laser and optical sensors for this experiment need to be capable of illuminating at a reasonably high rate, all of the retroreflector targets and processing the reflected signals within a reasonably short period to detect all the vibration modes of interest associated with shape distortion on the reflector surface. As an example, the JPL Spatial High-Accuracy Position Encoding Sensor (SHAPES) can process signals at the digital rate of 10 samples/s and can detect essential vibration modal frequencies up to 5 Hz. Design of an appropriate laser and optical sensor unit will represent a major challenge. Proper location of retroreflector targets, typically mirror segments, will enhance the amount of information generated as a sensed input to the adaptive control system and will require a significant amount of analysis to seek near optimum strategies. Adjustment of the retroreflector targets may be part of the experiment reconfigurations.



# TDMX 2411 (AAC) INSTRUMENTATION LIST

HUB RATE GYRO PICK-OFFS 3

## ACCELEROMETERS

SHORT BOOM 9  
LONG BOOM 15  
INSTRUMENTATION SUPPORT BOOM 15

## ANGULAR POSITION PICK-OFFS

PROXIMITY SENSOR 3  
LASER SENSOR 3  
BOOM CONTROLLER 3

STRAIN GAGES (ON LONG BOOM) 6 \*  
DRIVING CURRENT FOR ACTIVE PROOF MASS  
ACTUATORS - CURRENT DETECTORS 3 \*

\* SENSING ADDED TO THE TDMX 2071 LIST FOR THIS TDMX

SAMPLING RATE = 10/SEC



## TDMX 2412

### DISTRIBUTED CONTROL EXPERIMENT CONCEPT

- OBJECTIVE

To validate distributed control hardware, algorithms and systems for active vibration damping, cooperative payload pointing, modular control, control during deployment, and precision pointing/stabilization.

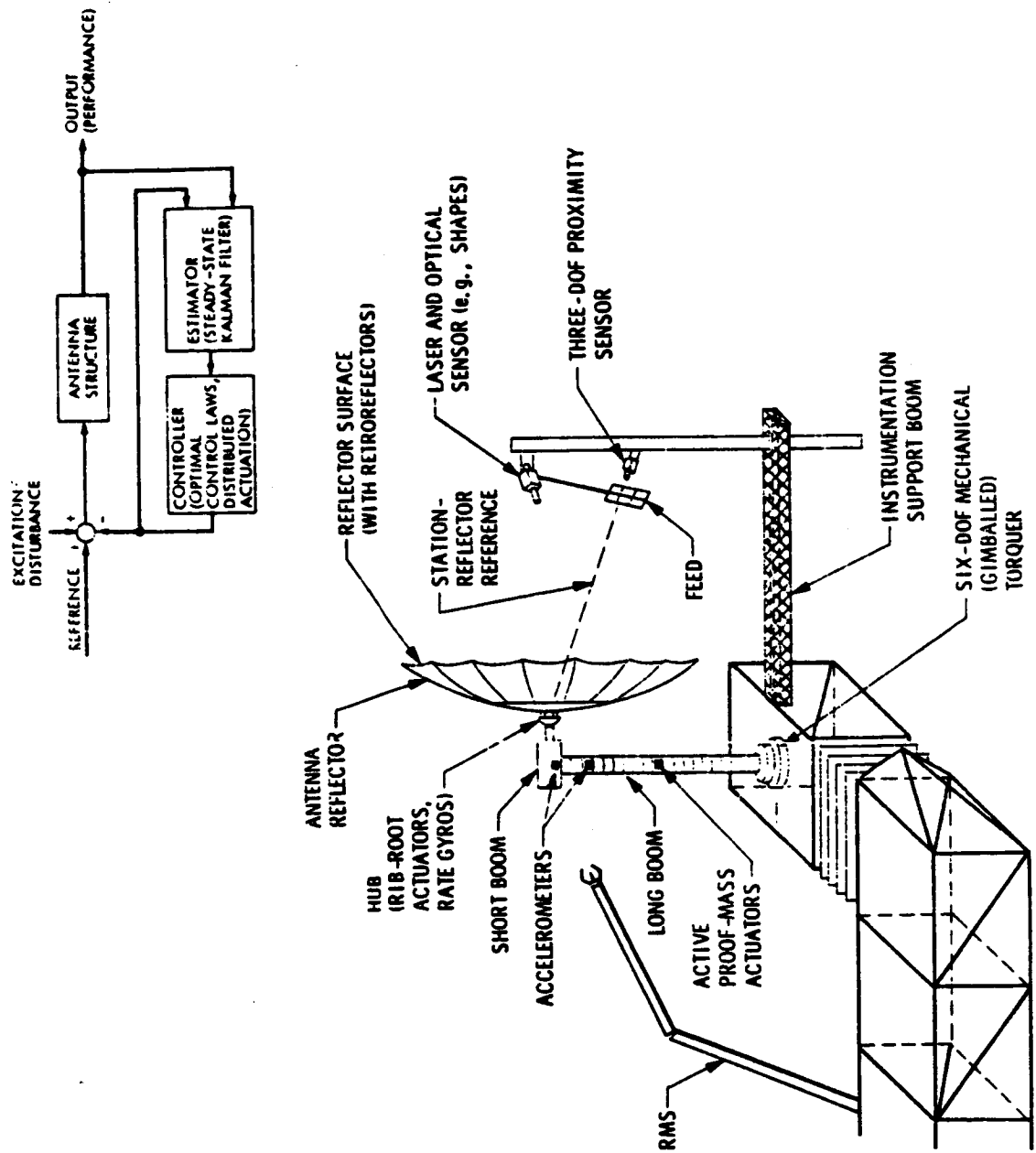
- DESCRIPTION

The experiment, defined on the facing chart, consists of multi-point payload vibration/shape sensing with a sensor attached to Space Station. Distributed actuation along the experimental structure will allow optimal placement of actuators and control schemes. Articulation and deployment of payloads will assist in further understanding of control variations as the structural configuration changes. TDMX 2412 will utilize the equipment from TDMX 2071 and TDMX 2411. TDMX 2412 will be continued as a subset of TDMX 2413.



# TDMX 2412

## DISTRIBUTED CONTROL EXPERIMENT CONCEPT





## **TDMX 2412 DCE EQUIPMENT LIST**

The equipment list on the facing page is the same as the one for TDMX 2411 and will serve the distributed controller experiment, TDMX 2412. Reconfiguration of the actuator and sensor components and the laser retroreflectors may, however, be appropriate for this TDMX.

The distributed control algorithms will be available in the form of control software residing in mission computers that will be installed in a pressurized module of the Space Station. Because of the complexity of the control algorithms, additional storage provided by the Station computer system may be required at different times in the course of the experiment.



# TDMX 2412

## DCE EQUIPMENT LIST

### EXTERNAL EQUIPMENT

- Antenna reflector
- Rate gyros at antenna hub
- Mechanical torquer
- Short boom
- Long boom
- Instrumentation support boom
- Laser and optical sensor unit
- Retro reflector targets
- Active proof-mass actuators
- Strain gages
- Rib-root actuators
- Boom mounted accelerometers

### INTERNAL EQUIPMENT

- Rack mounted mission data instruments
- Data processor (capability equivalent to 1 hr of VAX 11780 each operational day)
- Multifunction keyboard
- Data recorder (142 MBITS capacity)
- Display for monitoring sensors and digital data
- Closed circuit TV display via CRT



## **TDMX 2412 (DCE) INSTRUMENTATION LIST**

The chart on the facing page gives an initial estimation of the list of instrumentation needed for TDMX 2412. It should be noted that the list is the same as the one presented for TDMX 2411.

The experiment will require the use of about 40 retroreflector targets, typically mirror segments, to be placed on the antenna reflector surface and the long and short booms. Other sensors, such as rate gyros, accelerometers, and strain gauges will also be placed on the long and short booms.



## TDMX 2412 (DCE) INSTRUMENTATION LIST

---

HUB RATE GYRO PICK-OFFS	3
ACCELEROMETERS	
SHORT BOOM	9
LONG BOOM	15
INSTRUMENTATION SUPPORT BOOM	
ANGULAR POSITION PICK-OFFS	15
PROXIMITY SENSOR	3
LAZER SENSOR	3
BOOM CONTROLLER	3
STRAIN GAGES	
DRIVING CURRENT - CURRENT DETECTORS	6
(ACTIVE PROOF MASS ACTUATORS)	3

SAMPLING RATE = 10/SEC



## TDMX 2413

### DYNAMIC DISTURBANCE EXPERIMENT CONCEPT

- **OBJECTIVE**

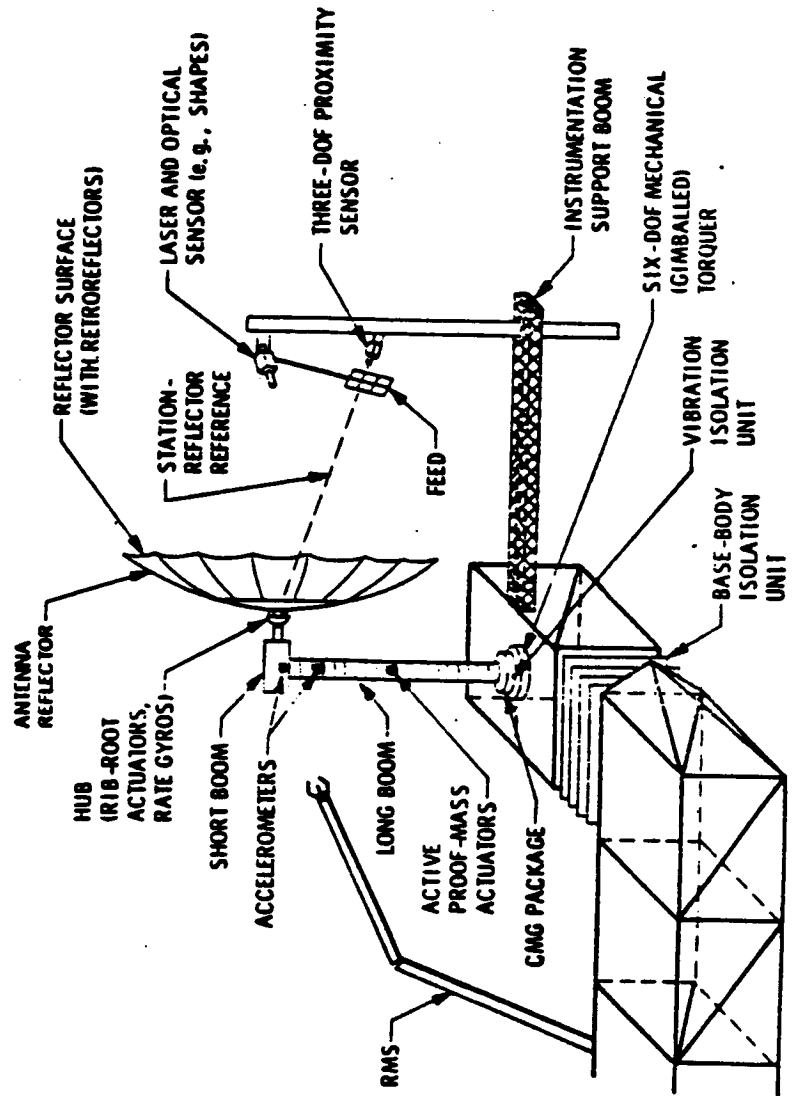
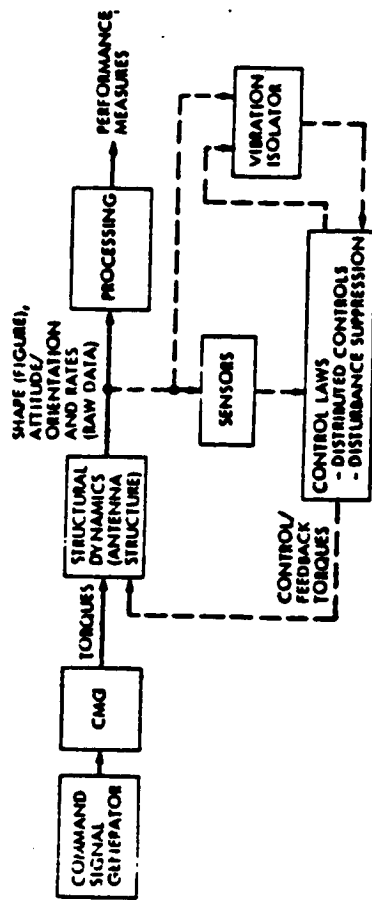
To evaluate methods of damping various disturbance torques from manned and other payload operations to permit precision pointing by the Space Station.

- **DESCRIPTION**

The control package would be installed on the Space Station at a desirable location, typically as a pallet payload installation. It would be capable of initiating control disturbances similar to those expected during future payload operations and capable of initiating selected means of damping these disturbances. The performance of these damping methods would then be determined and evaluated. TDMX 2413, as illustrated on the facing page, will utilize equipment from TDMX 2071, 2411, and 2412.



# DYNAMIC DISTURBANCE EXPERIMENT CONCEPT





## TDMX 2413 DDE EQUIPMENT LIST

All experiments for TDMX 2413 will involve the use of the antenna structure deployed for TDMX 2071 which, is composed of an antenna reflector supported by a boom geometry that consists of a long and short boom. That TDMX 2071 structure includes a six-degree-of-freedom (DOF) gimballed torquing device, on which the long boom is installed at the base. This will provide slewing, rotations, and mechanical excitations for the antenna structure. For TDMX 2413, the gimballed torquing device will be used with a Control Moment Gyro (CMG) package to provide controlled and calibrated slewing motion. During the final phase of experimentation for TDMX 2413, a vibration isolation unit will be placed between the gimballed torquer and the long boom for tests to reduce disturbance effects. A specially designed base-body isolation unit will be placed between the truss structure that supports the antenna and the Space Station upper boom for TDMX 2413. Its purpose will be exclusively to provide insulation for the mission test articles from disturbance effects originating in the Station core.

The disturbance suppression and isolation algorithms will be used in a software module with a distributed control and adaptive control software package in the mission computer. Because of algorithm size and overall complexity, use of the Space Station computer may be necessary for certain parts of the experiment.



# TDMX 2413

## DDE EQUIPMENT LIST

---

EXTERNAL EQUIPMENT	INTERNAL EQUIPMENT
• Antenna reflector	• Rack mounted mission data instruments
• Rate gyros at antenna hub	• Data processor (capability equivalent to 1 hr of VAX 11780 each operational day)
• Mechanical torquer	• Multifunction keyboard
• Short boom	• Data recorder (142 MBITS capacity)
• Long boom	• Display for monitoring sensors and digital data
• Instrumentation support boom	
• Laser and optical sensor unit	• Closed circuit TV display via CRT
• Retro reflector targets	
• Active proof-mass actuators	
• Strain gages	
• Rib-root actuators	
• Boom mounted accelerometers	
• Base-body isolation unit *	
• CMG package/vibration isolation unit *	

\* Added to TDMX 2411/2412 equipment for TDMX 2413



## TDMX 2413 (DDE) INSTRUMENTATION LIST

The list on the facing page is an estimation of the types and numbers of sensors for TDMX 2413. The additional instrumentation for this TDMX includes the pick-offs and excitation associated with the CMG package and the isolation units.

The sensors will detect force and torque disturbances and figure or shape distortions.

The laser and optical sensor unit has to be capable of illuminating at a reasonably high rate all of the retroreflector targets, and processing the reflected signals within a sufficiently short period to detect all the vibration modes of interest associated with shape distortion on the reflector surface. As an example, the JPL Spatial High-Accuracy Position Encoding Sensor (SHAPES) can process signals at the digital rate of 10 samples/s, and therefore be potentially able to detect vibration modal frequencies up to 5 Hz. Design of an appropriate laser and optical sensor unit will represent a major challenge. In addition to this, proper location of retroreflector targets, which are typically mirror segments, will enhance the amount of information generated as a sensed input for the distributed multi-point feedback control system, and will require a significant amount of design analysis to formulate near-optimum strategies.



# TDMX 2413 (DDE) INSTRUMENTATION LIST

---

HUB RATE GYRO PICK-OFFS	3
ACCELEROMETERS	
SHORT BOOM	9
LONG BOOM	15
INSTRUMENTATION SUPPORT BOOM	15
ANGULAR POSITION PICK-OFFS	
PROXIMITY SENSOR	3
LAZER SENSOR	3
BOOM CONTROLLER	3
STRAIN GAGES	
BOOM DEFLECTION MEASUREMENTS	6
ISOLATION UNIT	12
DRIVING CURRENT DETECTORS	
ACTIVE PROOF MASS ACTUATORS	3
CMG TORQUING MOTORS	3
CMG RATES PICK-OFFS	3

SAMPLING RATE = 10/SEC



MICROELECTRONICS DATA SYSTEM EXPERIMENT CONCEPT

- OBJECTIVE

To operate in a realistic space environment the microelectronic and optoelectronic components of advanced, high-data-rate data systems in order to establish the space worthiness of the technology; including VLSI components, integrated optics and fiber optic components, data bus technology and data transmission in the microwave bandwidth.

- DESCRIPTION

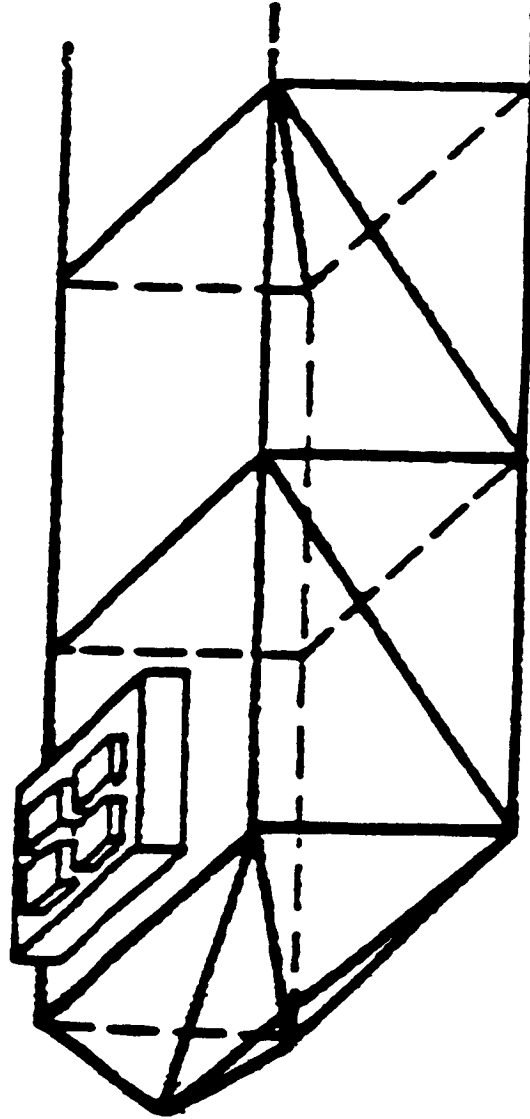
The experiment, conceptual illustrated on the facing page chart, will develop a long-term data base on the performance of advanced microelectronics and optoelectronic data system components for the Space Station and other space systems. It will have the flexibility to incorporate new and developing technologies, including silicon and gallium arsenide VLSI as well as optoelectronic components. The experiment will test concurrently 3 independent data system/component modules. The experiment will operate semi-autonomously and be externally deployed. The mission will consist of a 5-10 year program, with annual recovery of exposed/tested modules and installation of new modules. The Space Station will provide means for necessary long-term exposure to the environment (including low-dose-rate effects).



TDMX 2441

# MICROELECTRONICS DATA SYSTEM EXPERIMENT CONCEPT

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## TDMX 2441 (MDSE) EQUIPMENT LIST

The list on the facing page indicates the equipment for TDMX 2441 and shows that the experiment consists entirely of external equipment.

The experiment tray for TDMX 2441 will serve as an experiment module holder. Its function is mechanical, to hold the experiment and support modules and associated connectors.

The tray's dimensions will be on the order of 1 m x 2 m x 1/2 m and will accommodate four modules about 45 cm on a side.

One of the four modules is a support module that would contain common data-handling, power, and control functions. The provision of these general support functions on a separate module will permit modification or updating during multi-year project if new experiment modules require it. The other three modules are separate test article modules for examination in the space environment. These modules may be changed during the annual reconfigurations of this experiment. On/off commands for this experiment may be implemented through use of the standard APAE facilities.



## **TDMX 2441 (MDSE) EQUIPMENT LIST**

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### **EXTERNAL EQUIPMENT**

- Experiment tray
- Four plug-in experiment modules in the tray
- One of the four modules is for data handling, power conditioning and control support of the other three

### **INTERNAL EQUIPMENT**

- None



## **TDMX 2441 (MDSE) INSTRUMENTATION LIST**

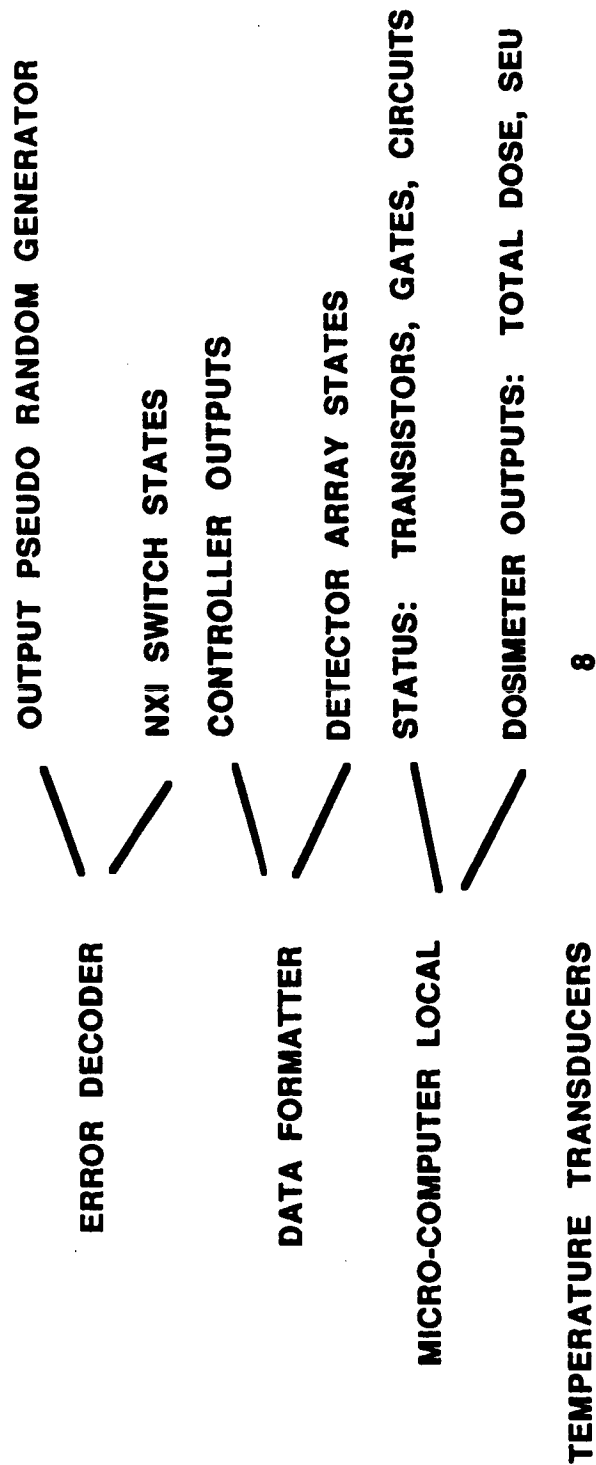
The facing page indicates that the data generated by this experiment is processed by the support module into a digital data stream for downlink. The items listed are examples of processing functions performed by the support module and indicate some types of inputs which may be processed. Except for the temperature transducer outputs the data is formatted and compressed into a data stream which can be downlinked with minimal processing by the Space Station communication system.



# TDMX 2441 (MDSE) INSTRUMENTATION LIST

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## DIGITAL DATA STREAM



TEMP 0.1/SEC (ONCE EVERY 10 SECS)

DIGITAL DATA = 42 KBPS DATA RATE

AT 32 BITS PER SAMPLE GIVES 1300 SAMPLES/SEC?



# TDMX 2462 DEXTROUS TELEOPERATOR

## EXPERIMENT CONCEPT

- OBJECTIVE

To evaluate and demonstrate the use of advanced teleoperation techniques using computer and sensor-aided manual/automatic control in a "stationary" and "dynamic" Space Station environment. "Stationary" refers to teleoperation where the job to be performed is stationary relative to the manipulator base. "Dynamic" teleoperation refers to the case where the teleoperated servicer is moving with respect to the satellite on which the job is to be performed. Typical maintenance/servicing jobs will be demonstrated.

- DESCRIPTION

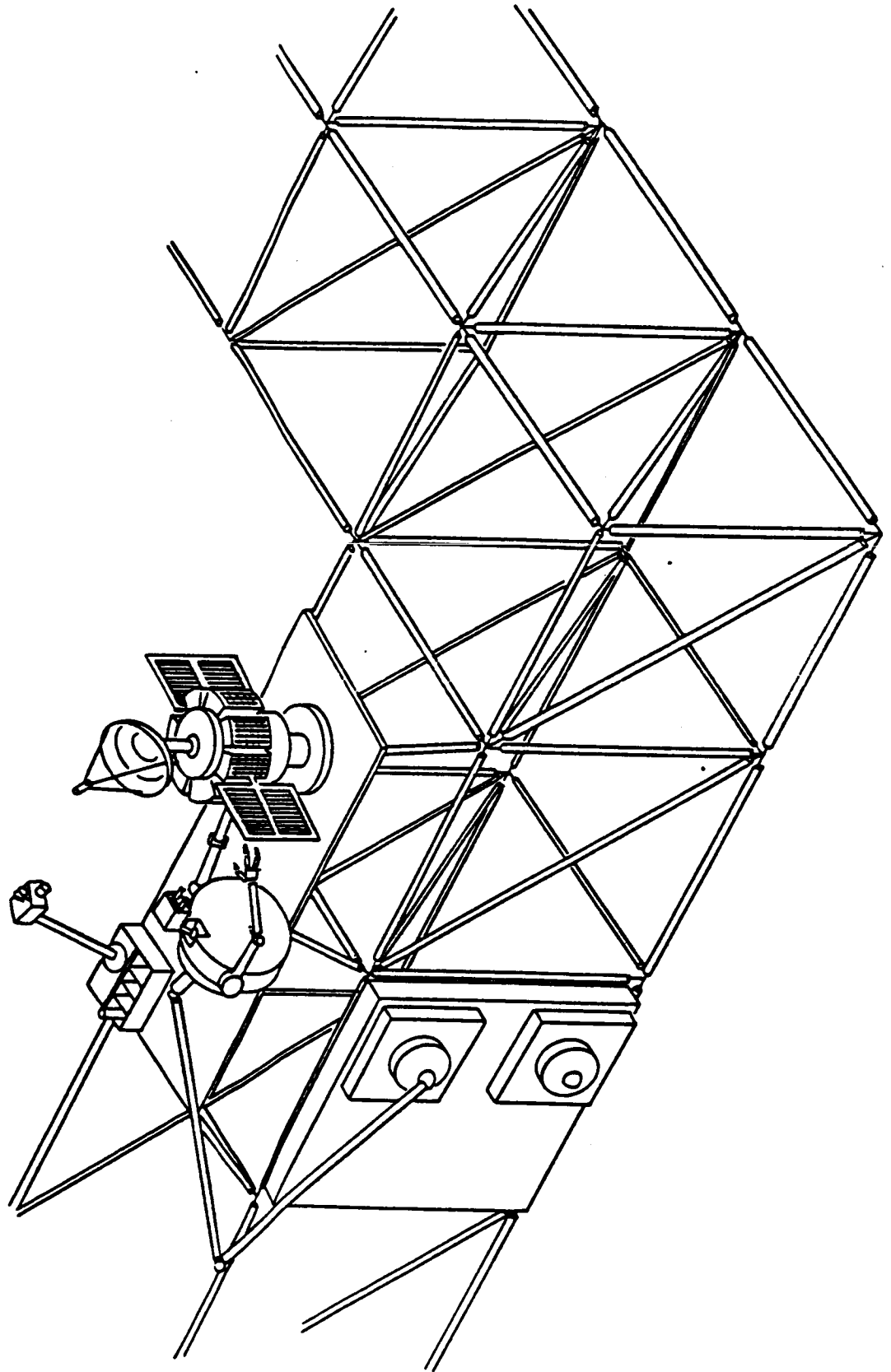
This mission, depicted on the facing chart, is the first of the 2460 category missions performing teleoperation experiments. Two small manipulator arms (2m category) on a servicer unit which is attached to the MSC arm will perform dexterous jobs on a model satellite. The model satellite will be attached to the Space Station structure. Servicing jobs will be performed, using teleoperations coordinated with MSC Control, e.g., screwing, latching, module replacement, and coupler mating.



TDMX 2462

# DEXTEROUS TELEOPERATOR EXPERIMENT CONCEPT

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## TDMX 2462 (DTTE) EQUIPMENT LIST

The facing page provides a list of external and internal equipment identified by this study for TDMX 2462.

Although the MSC is intrinsically part of the Space Station and not unique to this mission, its role as transport and support system for the teleoperated servicer is indispensable to simulate servicer mobility for this experiment.

The teleoperated servicer can be attached and mated to the MSC through an umbilical link to become one unit, constituting a maneuvering teleoperated servicing system. The salient features of the teleoperated servicer are the manipulator arms of the 2-m category that will perform dexterous jobs on the model satellite. The station mounted CCTV pedestal will have two built-in racks: a component rack and an end-effector rack. The end-effector rack contains different hands for the servicer's manipulator arms. The servicer will carry no power sources and, by current design, will be supplied with 0.6 kW through cabling on the arms of the MSC when mated.

The model satellite will be attached to the Space Station APAE. It will be linked by live hook-up with the Space Station Control Center, so that it will not be required to carry its own power sources, and will send sensory feedback signals to the Space Station via hard wires, thereby facilitating data transmission with minimal environmental interferences. The model satellite acts essentially as an on-orbit satellite and is used as a test unit for teleoperated servicing in this experiment. It will therefore incorporate sensory test points, anchoring handles, and active satellite components to provide feedback for processing and recording.

Internal equipment includes a computer for real-time data storage and analysis, closed circuit television (CCTV) for visual contact and a teleoperated work station for perception and manipulation activities, cathode ray tubes (CRTs) and displays for observing the signals and data transmitted from the servicer and model satellite sensors.



# **TDMX 2462 (DTTE) EQUIPMENT LIST**

---

## **EXTERNAL EQUIPMENT**

- Teleoperated servicer unit (attached to MSC arm)
- Experiment unique cabling and support hardware on MSC arm
- Closed circuit TV unit and tool box (mounted on SS)
- Model satellite (mounted on SS)

## **INTERNAL EQUIPMENT**

- Teleoperator's work station
  - Two 6 DOF hand controllers
  - Stereo display
  - Two auxiliary graphics monitors (9 inch diagonal)
  - Multifunction display
  - Control switches and lighting on panel
- Work station support computer
  - D/A and A/D converters (SBX 328/SBX 311)
  - MUX/DMUX units
  - Processor (650 MBIT data storage) (SBC 286/12)
  - Digital interface unit



## **TDMX 2462 (DTTE) INSTRUMENTATION LIST**

The list on the facing page presents the instrumentation identified in this study for the Dexterous Teleoperator Technology Experiment (TDMX 2446)

The sensed data and video from the teleoperated servicer will be provided via an RF communications link or hardline through the MSC arm to the Space Station when the servicer is mated with the MSC, forming a remotely teleoperated system. The servicer sends video data to the Space Station, at 22,000 kb/s. The Space Station issues digital data commands to the servicer at 20 kb/s.



# TDMX 2462 (DTTE) INSTRUMENTATION LIST

ROBOT VIDEO	1
ROBOT ANGULAR POSITION PICK-OFFS	36
ROBOT RATE PICK-OFFS	36
ROBOT TORQUING CURRENT DETECTORS	36
ROBOT STRAIN GAGES	24
ROBOT TACTILE DETECTORS	120
CCTV VIDEO	1
CCTV ANGULAR POSITION PICK-OFFS	3
MSC ANGULAR POSITION PICK-OFFS	6
TEMPERATURE TRANSDUCERS	9

DATA RATE VIDEO 688,000 SAMPLES/SEC (32 BIT SAMPLES)  
OTHER 2500 SAMPLES/SEC



## TDMX 2461

# TELEOPERATED STRUCTURE ASSEMBLY EXPERIMENT CONCEPT

- OBJECTIVE

To demonstrate and evaluate the use of advanced teleoperation techniques to perform structures assembly. Advanced teleoperation techniques include computer and sensor-aided manual and automatic control, as demonstrated in TDMX 2462.

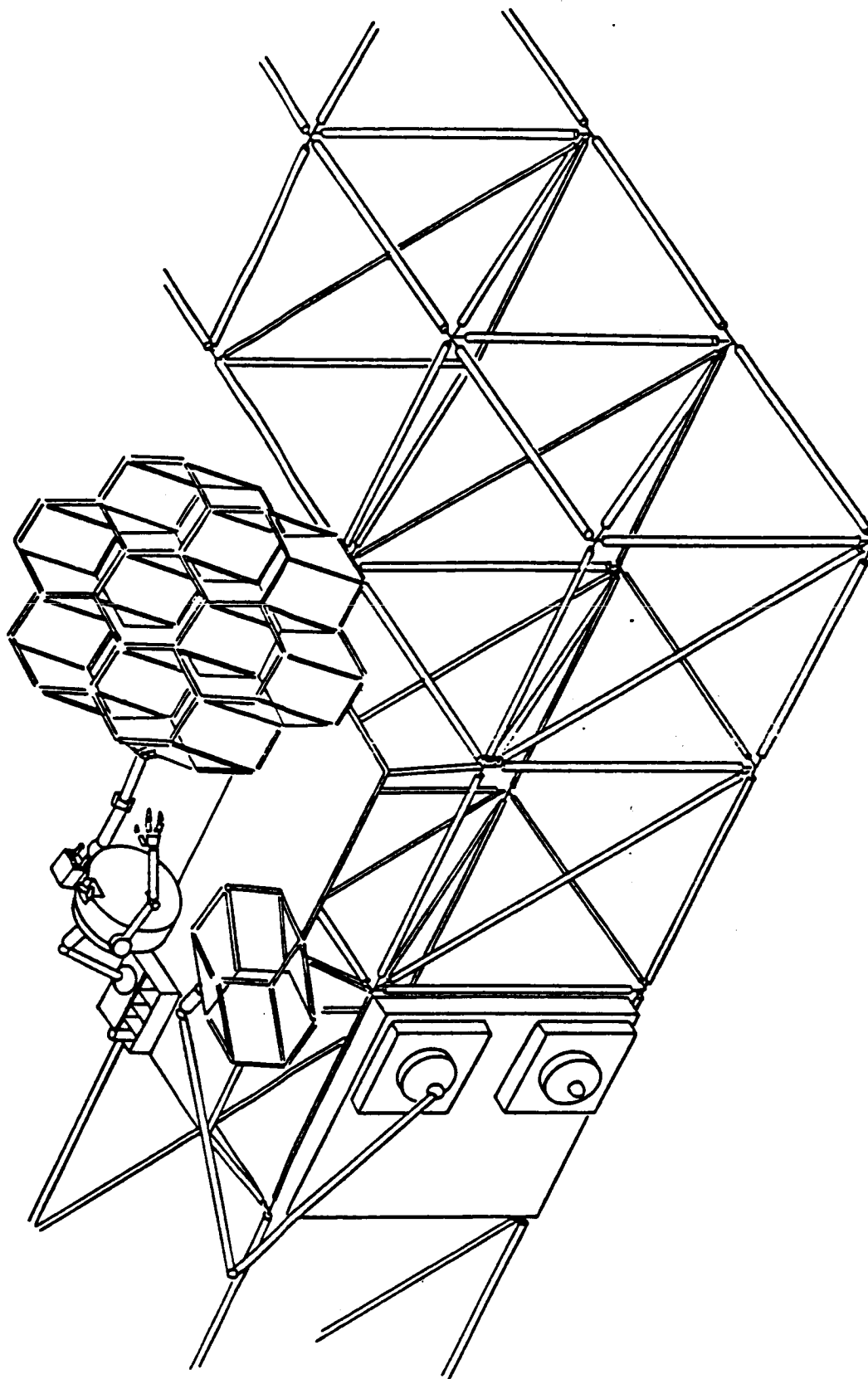
- DESCRIPTION:

This mission, illustrated on the facing chart, is one of the category 2460 missions performing teleoperation experiments. Structures assembly will be demonstrated in this mission. The hardware includes a "teleoperator assembler" (TA) which will be attached to the keel on the Space Station. The TA has two manipulator arms (5 m category), which are instrumented similar to the arms tested in TDMX 2462. In coordination with the Space Station MSC, these arms will assemble trusses and/or mirror segments, thus establishing and demonstrating routine teleoperation procedures.



**TDMX 2461**  
**TELEOPERATED STRUCTURE ASSEMBLY EXPERIMENT CONCEPT**

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## TDMX 2461 (TSA) EQUIPMENT LIST

The facing page chart lists external and internal equipment for the teleoperated structure assembler experiment (TDMX 2461).

The external equipment will be comprised of the teleoperated assembler (TA), truss bundles for assembly, a fixture to hold the truss bundles and a pedestal from which the TA is articulated. The equipment will be attached to the Space Station using standard payload attach equipment and the pedestal may be a version of the payload pointing system. The equipment will be mounted on the station APAE using EVA and the MSC prior to beginning the TDMX 2461 experiments. The TA will derive power from hard wires running in the station structure to support the APAE. The TA unit will have multiple manipulator arms of the 5 m category. The end effector rack, in which different interchangeable and effectors are stored, will be attached to the pedestal. For the purpose of experimentation the station MSC must be properly positioned so that its manipulator arm can be used to hold the structures as they are being assembled.

The internal equipment is comprised mainly of data processing and control and monitoring devices that primarily track and record the sensed feedback signals and data (e.g., force-torque signals that arise as a result of using the TA manipulator arms for assembly activities). The equipment includes data processors, cathode ray tubes (CRTs), special displays, closed-circuit televisions (CCTVs), screens/monitors, and displays will be placed in the Station Control Center.



## **TDMX 2461 (TSA) EQUIPMENT LIST**

---

### **EXTERNAL EQUIPMENT**

- Teleoperator assembler (TA)
- TA mounting pedestal
- Structural elements for assembly
- Holding fixture for structural elements

### **INTERNAL EQUIPMENT**

- Teleoperator's work station
  - Two 6 DOF hand controllers
  - Stereo display
  - Two auxiliary graphics monitors (9 inch diagonal)
  - Multifunction display
  - Control switches and lighting on panel
- Work station support computer
  - D/A and A/D converters (SBX 328/SBX 311)
  - MUX/DMUX units
  - Processing (650 MBIT data storage capacity) - (SBC 286/12)
  - Digital interface unit



## TDMX 2461 (TSA) INSTRUMENTATION LIST

Instrumentation estimates for the teleoperated structure assembler experiment (TDMX 2461) are indicated on the facing page listing.

The external and internal equipment is linked by hard wires and possibly local RF for this mission. The experimental data originating in the TA is transmitted to the mission specialist inside the Space Station at a real-time rate of 20 to 90 kb/s for 9 h each day in one continuous session. Visual monitoring is achieved by CCTV or stereo-optics concepts. Video data will be generated at the rate of 22,000 kb/s for 2 h each day. Ground personnel will be communicating with the Space Station via digital data.



# TDMX 2461 (TSA) INSTRUMENTATION LIST

## ROBOT DATA

VIDEO .....	1
ANGULAR POSITION PICK-OFFS	
ROBOT FINGER JOINTS .....	18
ROBOT HAND/WRIST JOINTS .....	8
ROBOT ARM JOINTS .....	10
ANGULAR RATE PICK-OFFS	
.....	36
TORQUING CURRENT - - CURRENT DETECTORS - -	36
STRAIN GAGES .....	24
TACTILE FEEDBACK DETECTORS .....	120
TEMPERATURE TRANSDUCERS .....	6

DATA RATE .....	VIDEO 688,000 SAMPLES/SEC (32 BIT SAMPLES)
	OTHER 2500 SAMPLES/SEC



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# **Langley Research Center Proposed Technology Development Mission Experiments**



## **TDMX 2011. SPACECRAFT MATERIALS AND COATINGS**

**PI: DR DARREL R. TENNEY AND WAYNE S. SLEMP/LARC, (804) 865-3420**

- **OBJECTIVE**

The overall goal of this TDMX is to provide a technology base for the development of advanced structural materials; optical, thermal and absorbing coatings; and diverse components for long-term use in the space environment. Emphasis will be placed on obtaining data for the identification of damage mechanisms and formulation of degradation models to guide future materials development.

- **DESCRIPTION**

The proposed experiment will provide a unique opportunity to develop a long-term space environment durability data base on advanced thermal control coatings, adhesives, polymeric matrix composites, and polymer films. Specific experiments will be developed to evaluate the effects of each exposure parameter, both singly and combined on the properties of these materials. Insitu evaluation of properties will be performed using three panels carrying specimen trays as depicted on the facing page chart. Test specimens will be monitored, tested on site, replaced, and returned to earth for extensive testing. Specific areas will include spacecraft materials technology, materials and coatings technology, and space component lifetime technology. Power and data links will be supplied by the Space Station.



# TDMX 2011

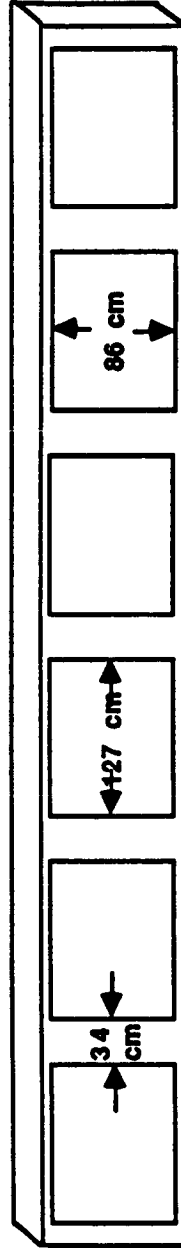
## Spacecraft Materials and Coatings

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### Panel Concepts

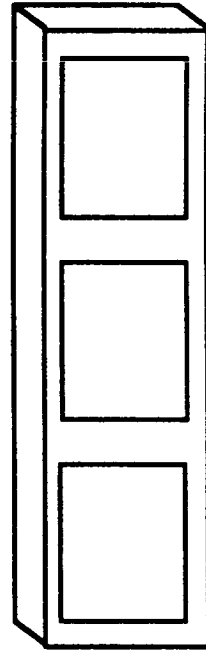
(a) Velocity-Facing

Width: 1 m  
Length: 10 m  
Depth: 0.2 m



(b) Wake- and Sun-Facing

Width: 1m  
Length: 5m  
Depth: 0.2m





## **EXAMPLE EXPERIMENT TRAY**

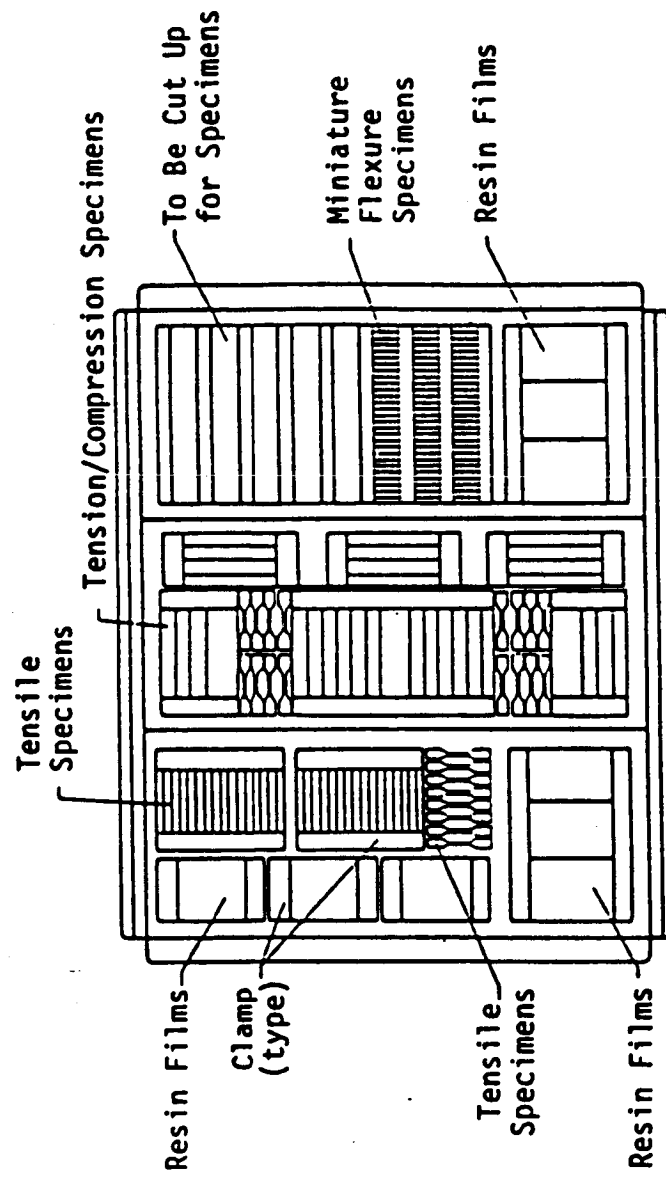
The execution of the subject materials and coatings experiment will utilize experiences gained from the Long Duration Exposure Facility (LDEF) activities. Placement of specimen trays, their recovery, experiment control, and data acquisition will incorporate the increased flexibility allowed by the Space Station.

Specific experiments will be developed to evaluate the effects of various exposure parameters (e.g., atomic oxygen, solar radiation, temperature, solar flare, etc.) both individually and combined, on the properties of the test samples. The chart on the facing page shows a passive tray typical of that flown on LDEF containing material samples which would be exposed and then returned to earth for extensive laboratory examination and testing. Active trays will also be employed. These will be instrumented with equipment to monitor environmental exposure parameters, and specimen optical properties and weight loss during their exposure.



# Example Experiment Tray

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Dimensions of Trays (after LDEF): Width - 34" (86.36 cm)  
 Length - 50" (127 cm)  
 Depth - 6" (15.24 cm)  
 (Weight - ~ 80 lbs typically)

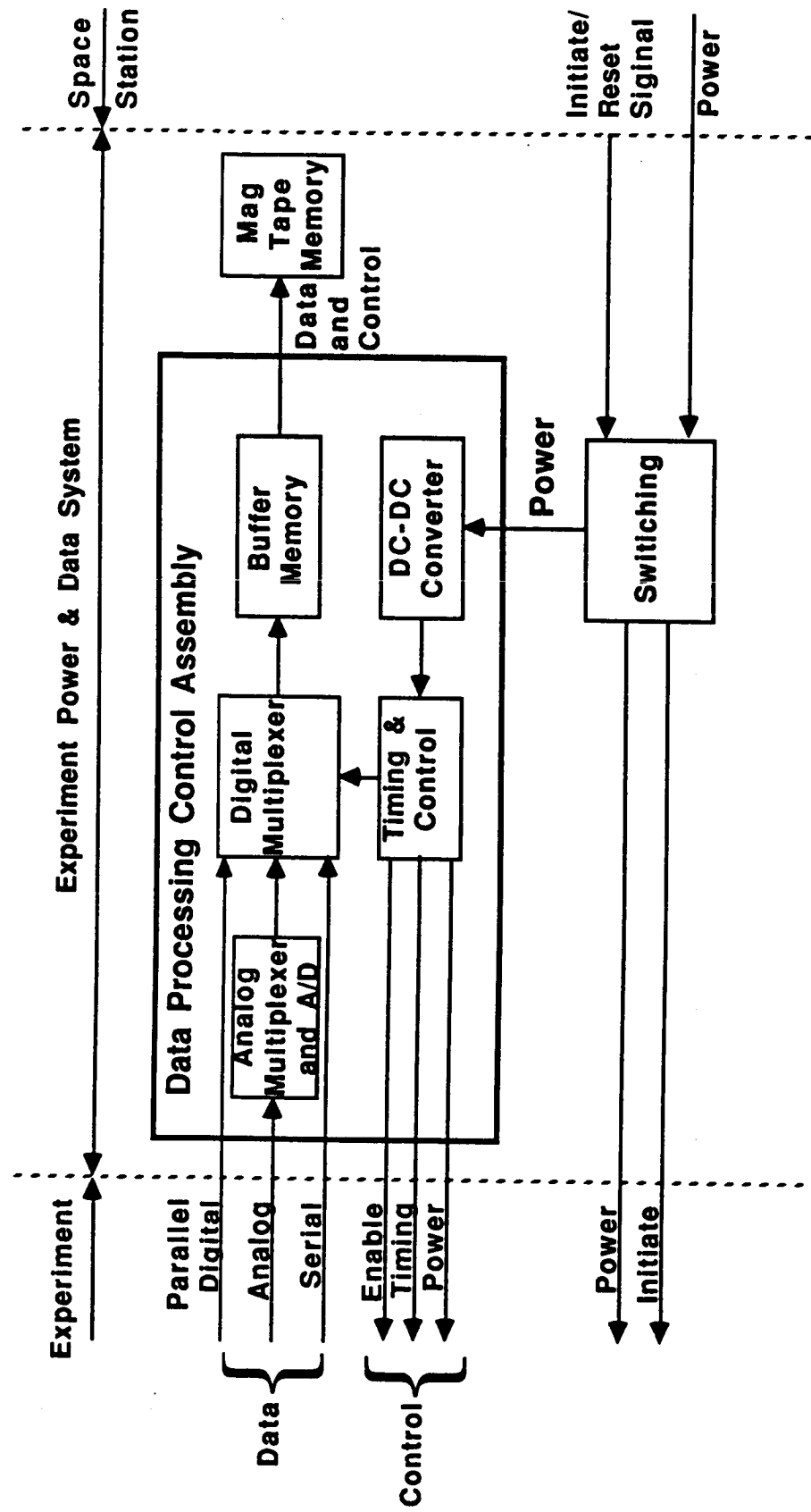


## **EXPERIMENT CONTROL AND DATA SYSTEM BLOCK DIAGRAM**

The data handling and storage system for this experiment must have the capacity to process and record information from many separate digital and analog data channels. The system must be user programmable to provide the desired timing for data collection and the desired binary word length used in the A/D conversion of analog data. Use of a data handling and storage system similar to that qualified for the Long Duration Exposure Facility would adequately meet the expected inflight processing and recording requirements for this TDMX. LDEF used an experiment power and data system (EPDS) for control and data collection for which a functional block diagram is shown on the chart on the facing page.



# Experiment Control & Data System Block Diagram





# TDMX 2072. SPACECRAFT STRAIN AND ACOUSTIC SENSORS

PI: DR JOSEPH S. HEYMAN/LARC, (804) 865-3036

- OBJECTIVE

The overall objective of this effort is to develop and demonstrate a structural monitoring "nervous" system for the Space Station to provide crew, mission control, and ground based contractors with real-time structural status, including analysis of unexpected events such as "hard docking" or debris/meteor impact. This experiment will develop the technology necessary to monitor spacecraft structures and provide long-term structural verification through advanced nondestructive evaluation (NDE). Testing such systems on early space missions prior to Space Station flight to validate performance and assure meeting Space Station monitoring needs is envisioned.

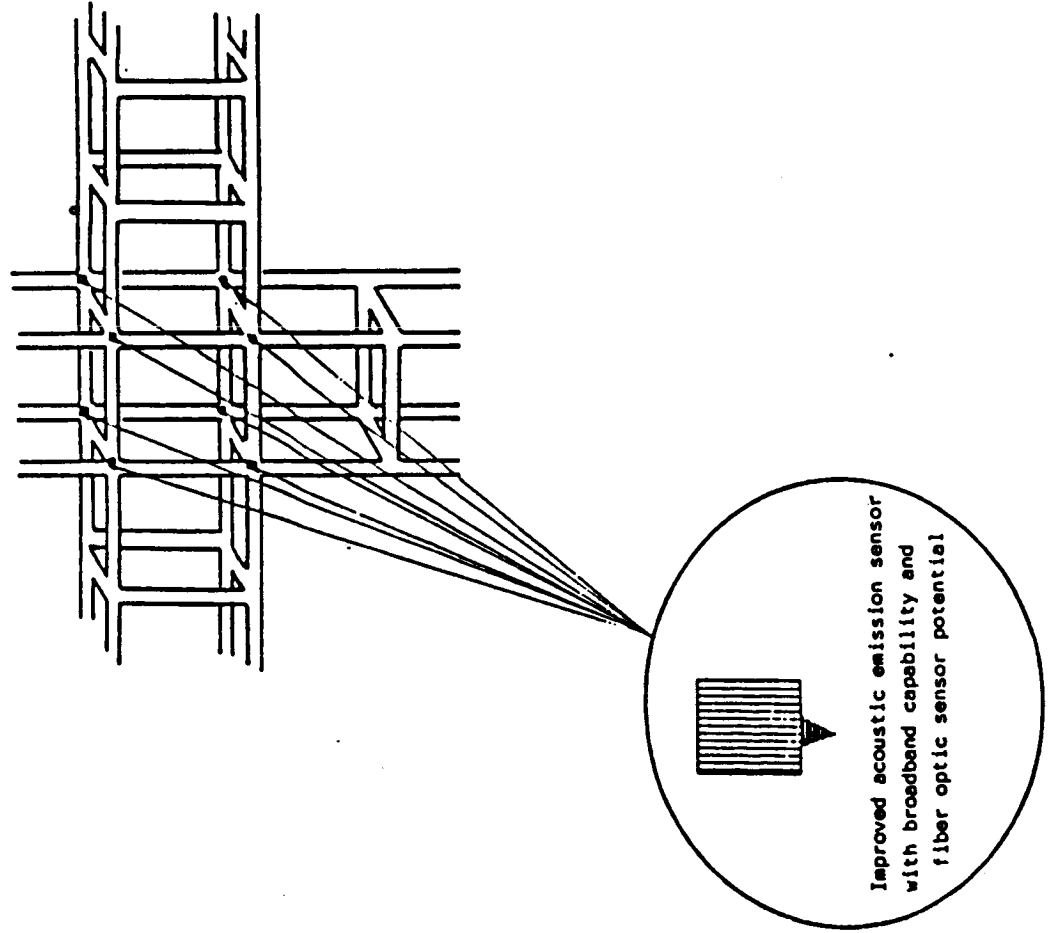
- DESCRIPTION

Advanced acoustic emission sensors designed and built into the space station structure, as illustrated on the chart on the facing page, will be monitored during the mission. The sensors will be developed and tested on the ground and will take advantage of current R&D program output to provide state-of-the-art sensors. Additional sensors designed to monitor strain with acoustics and fiber-optic interferometric techniques which have been developed at LaRC will be structurally integrated as well.



# TDMX 2072, Spacecraft Strain And Acoustic Sensors

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# SPACE STATION STRUCTURAL PERFORMANCE EXPERIMENT

PI: James W. Johnson/LaRC, (804) 865-4834

- OBJECTIVE

The overall goal of this proposed TDMX is to obtain actual on-orbit research data for extended performance characterization of the Space Station (SS) to support the development of analytical models in structural dynamics and structure/controls interaction. Specific objectives include the measurement of modal frequencies, mode shapes, damping characteristics, and local disturbance responses for system identification, plus the definition of thermal effects and the development of non-destructive structural evaluation methods.

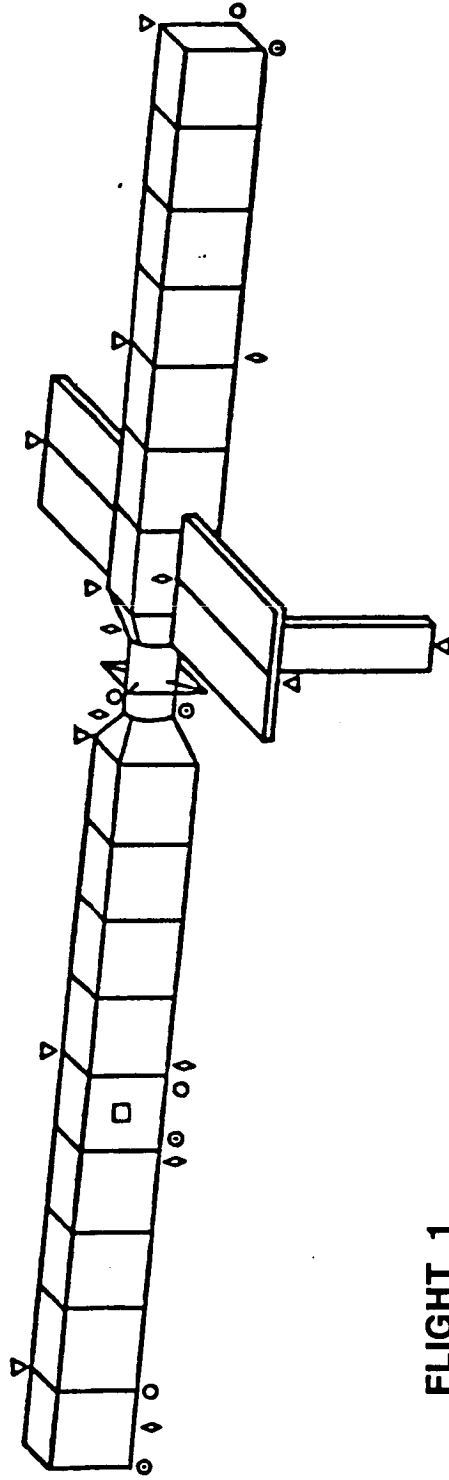
- DESCRIPTION

The plan is to utilize the SS elements at each stage of assembly. The facing page chart shows the first SS element as it would appear following on-orbit assembly. Required instrumentation is also identified and located. Needed structural response instrumentation will be integrated into each SS element during its fabrication. Following each assembly flight, the structural response of the current configuration to ambient and operational disturbances will be measured using the accumulated set of sensors. No vibration generating devices will be required. Excitation of the SS will occur naturally during normal operation (docking, thruster firing, solar array rotation, crew movement, etc). Although, the sensor set identified can be used for day-to-day monitoring of the structural integrity of the SS, that function is beyond the scope of this experiment.



# Space Station Structural Performance Experiment

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## FLIGHT 1

Port transverse boom  
Port solar arrays  
ACA module  
Energy storage module  
4 batteries  
Alpha joint  
Beta joint  
Berthing ring  
EPS radiator

## LEGEND

△ Accelerometers  
◇ Strain gauges  
○ Acoustic emission sensors  
○ Thermocouples  
□ Remote data processors



## EQUIPMENT/RESOURCE REQUIREMENTS SUMMARY

Preliminary estimates of the requirements for equipment and resources are given on the facing page chart. These requirements are for the fully assembled IOC Space Station, and will have minimal impact on its configuration, resources and operations.

The amount of data storage required depends upon the data processing and handling philosophy used as well as the number of channels of data, sampling rate, number of test periods, and the duration of each test period. The data storage requirement shown on the chart on the facing page is based on the assumption that there will be a maximum of 10 test periods of 120 seconds each, with a sampling rate of 50/second (sufficient to measure dynamic data up to 5 Hz), between each downlinking session. Note also, that these requirements do not include those for acoustic emission sensors which have frequencies up to 1.1 MHz; therefore, requiring MHz sampling rates.



## **Equipment/Resource Requirement Summary**

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•	<b>Sensors</b>	<b>896</b>
	<b>Strain Gauges</b>	<b>640</b>
	<b>Accelerometers</b>	<b>196</b>
	<b>Acoustic Emission Sensors</b>	<b>12</b>
	<b>Thermocouples</b>	<b>48</b>
•	<b>Data Rate</b>	<b>43 k bits/sec</b>
•	<b>Data Storage</b>	<b>52 M bits/orbit</b>
•	<b>Power</b>	<b>2.2 kW avg</b>
•	<b>Mass</b>	<b>283 kg</b>
•	<b>Remote Processors</b>	<b>5</b>
•	<b>Central Processor</b>	<b>1</b>



# TDMX 2442, TRANSIENT UPSET PHENOMENA IN VLSI DEVICES

PI: FELIX L. PITTS/LARC, (804) 865-3681

## • OBJECTIVE

The overall objective of this effort is to develop a data base which will contribute to the understanding of alpha particle and cosmic ray induced single event upsets in very large scale integrated (VLSI) devices. It is currently believed by most researchers in solid state electronics that neither shielding nor hardening will alleviate these problems completely for VLSI and higher circuit densities. Thus, there is a strong need to understand the nature of the system upsets that can be induced by the natural radiation environment in order to enhance the capabilities of future space applications of VLSI devices.

90

## • DESCRIPTION

The test article, depicted on the facing page chart, for this experiment will be specially fabricated for this purpose using state-of-the-art processes, and will include circuits to facilitate monitoring upset activity. There will be too primary components: The test unit (TU) and the monitor computer (MC). The TU will be a digital processor utilizing specially fabricated VLSI devices and programmed to perform a generic version of some critical space application function. The MC will be a highly-reliable, fault-tolerant, general-purpose computer programmed to perform the same application function, to determine when the TU has been upset, and record TU parameters at these times. This system will have excess computational capability which can be employed by other experiments on an as-available basis.



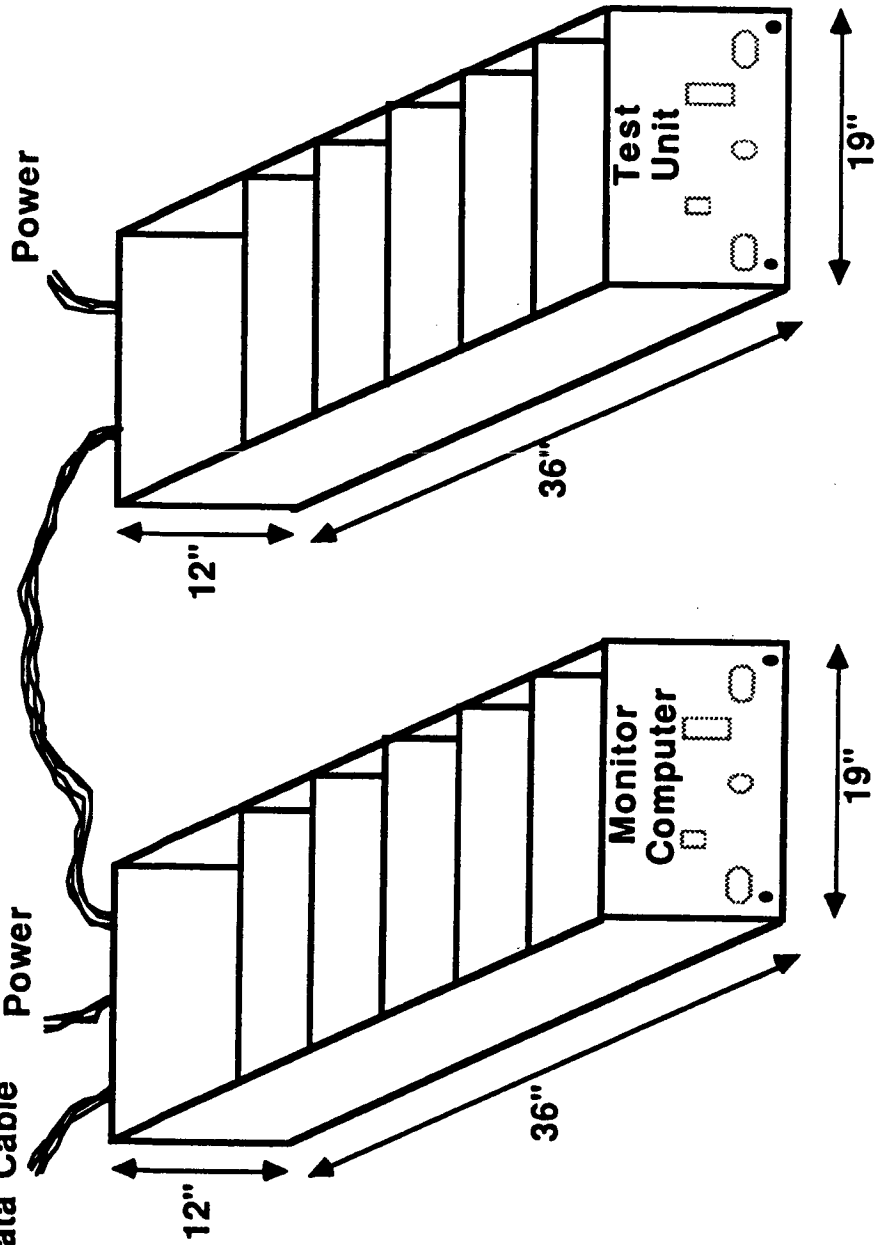
# TDMX 2442, Transient Upset Phenomena In VLSI Devices

## Experiment Configuration

Communication  
& Data Cable

Power

Power





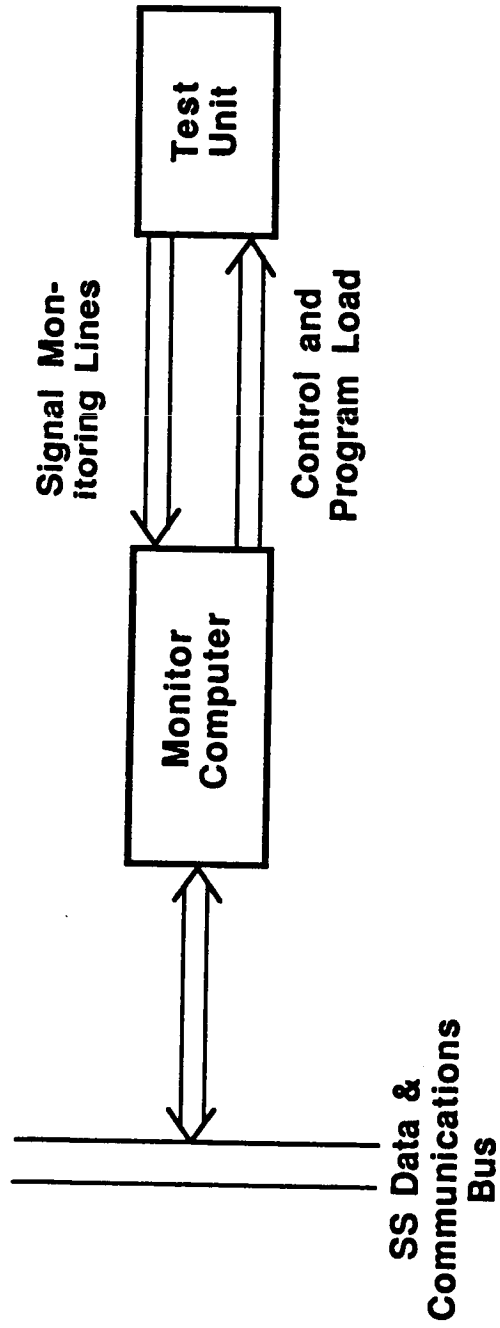
## EXPERIMENT BLOCK DIAGRAM

The facing page chart shows a block diagram of the planned experiment configuration. The test unit in this experiment is acting as a sensor since it reacts to the alpha particles, cosmic rays, and heavy ions of its environment. Unlike a more conventional sensor, however, the purpose of exposing it to this environment is not to make measurements of the radiation but to record the test unit's reaction to it. The test unit is simply a general-purpose digital processor system implemented on a VLSI chip which has been specially fabricated to allow enhanced fault detection and characterization. The parameters to be measured will be the outputs of the special monitoring circuitry on the chips, in addition to any data outputs from the program being run on the processor. The special monitoring circuitry will make lower-level functions of the system observable which would otherwise not be possible. These signals will include internal data, control, and address busses as well as register clocks and state vectors which are not normally available for monitoring. In addition, the monitor computer will require Space Station data from the on-board guidance, navigation, and control system. This data will be sampled whenever a system upset occurs in order to record the time, position, and orientation for the event.



# Experiment Block Diagram

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# TDMX 2443, VHSIC FAULT TOLERANT PROCESSOR

PI: DR. HARRY F. BENZ/LaRC, (804) 865-3535

- OBJECTIVE

The overall goal of this activity is to acquire realistic data on single event upset recovery by a self-testable, self-correcting computer using 1.25 micrometer very high speed integrated circuit (VHSIC) technology. This data will be used to establish a system error rate and statistical data base, and subsequently enhance the fault-tolerance of advanced systems, especially important for space applications in light of the increased radiation sensitivity of higher-density circuit technologies.

- DESCRIPTION

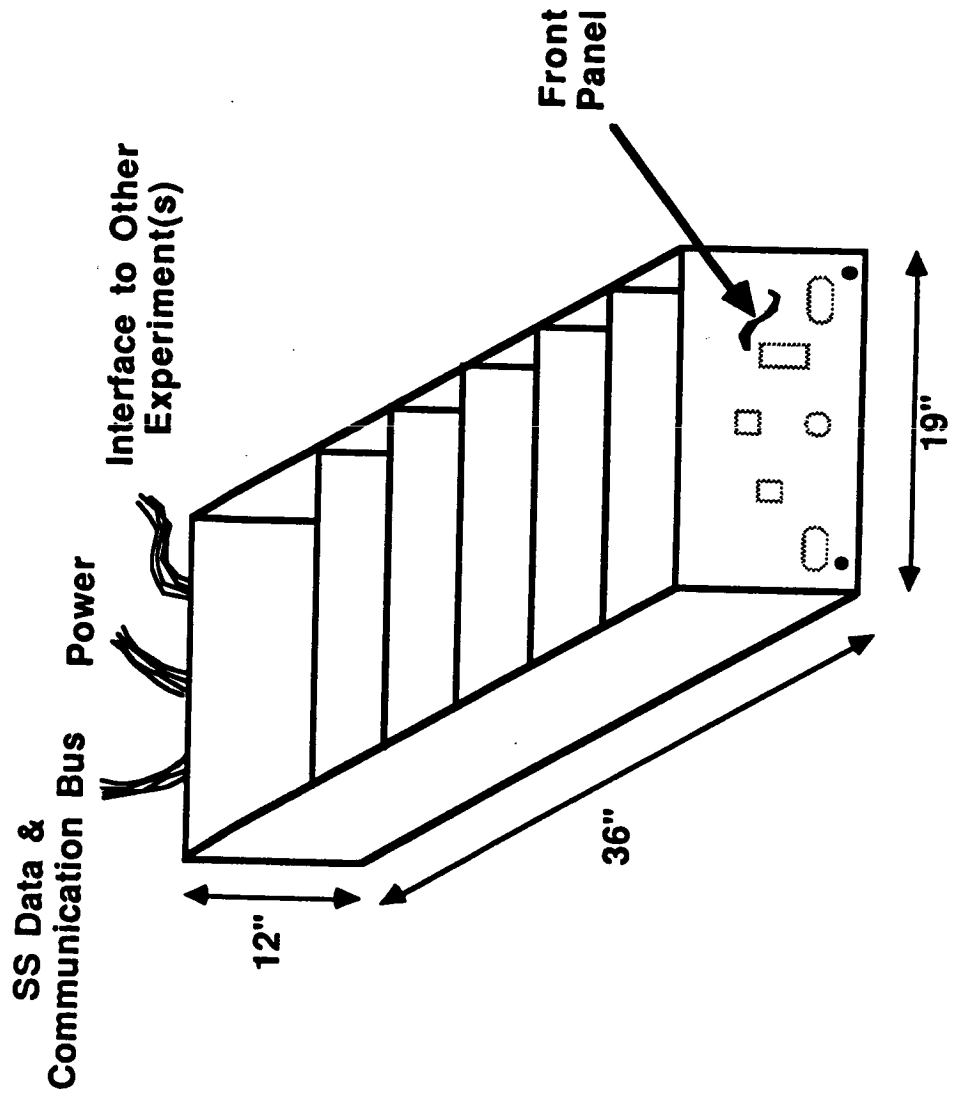
The experiment package, depicted on the chart on the facing page, will consist of a general-purpose computer designed around the VHSIC Phase I chip set, programmed for tasks which simulate mission-critical functions as well as fault monitoring activities. A high degree of fault tolerance will be achieved through the use of massive redundancy, with possibly as many as 6 redundant processors. The system will record fault detection and isolation sequences as well as the occurrence of hard faults and the resulting reconfiguration activities. Primary data acquisition will be performed by the fault-tolerant computer itself, and internally stored for subsequent interrogation by the Space Station data management system.



# TDMX 2443, VHSIC Fault Tolerant Processor

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## Experiment Configuration





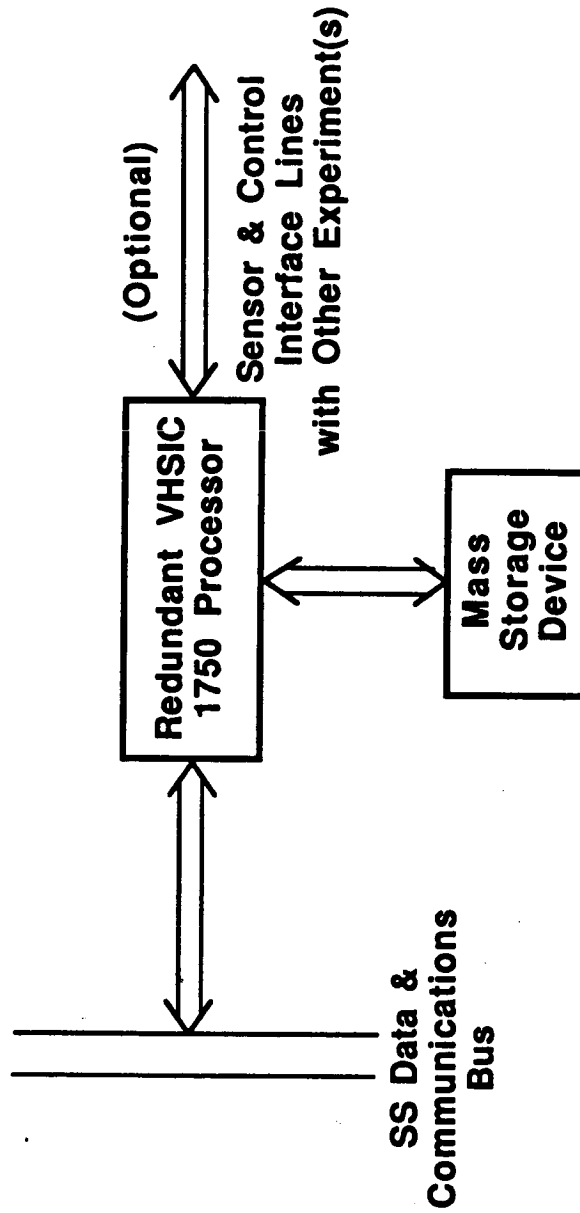
## EXPERIMENT BLOCK DIAGRAM

A block diagram of the planned experiment is shown on the facing page chart. The VHSIC processor used in this experiment is acting as a sensor in that it reacts to the radiation in its environment. Unlike a more conventional sensor, however, the purpose of exposing it to this environment is not to make measurements of the radiation but to record the system's reaction to it. Primary data acquisition will be performed by the fault-tolerant computer itself, and stored in on-board random access memory until it can be transmitted to the ground. A mass storage nonvolatile memory device which will also be used to supply programs to the system can be utilized for backup storage of data. An optical disc drive is being considered for this purpose. If a flight-qualified optical disc drive is not available for this experiment, bubble memory technology will be used for nonvolatile memory needs. The data system monitoring software will log all abnormal events, such as single event upsets, as well as gradual radiation degradation caused by integrated dose. In addition, the system will log the sequences for fault identification and isolation, chip self-test results, and system restoration modes. When hard faults are found it will log the fault site on the chip for future analysis and will reconfigure the system to accommodate faults. The system will require knowledge of the Space Station's position and attitude from the on-board guidance, navigation, and control system for the abnormal event log.



# Experiment Block Diagram

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# **Lewis Research Center Proposed Technology Development Mission Experiments**



## TDMX 2132, ADVANCED RADIATOR CONCEPTS

PI: ALDEN F. PRESLER/LeRC, (216) 433-6167

- OBJECTIVE

The overall end of this TDMX is to design and install a test bed integral and external to the Space Station for long term testing and evaluation of advanced space radiator concepts in the actual space environment and under the actual operating conditions they would experience in LEO. A selected number of advanced radiator concepts will be evaluated. A liquid droplet radiator concept is depicted on the facing page chart.

- DESCRIPTION

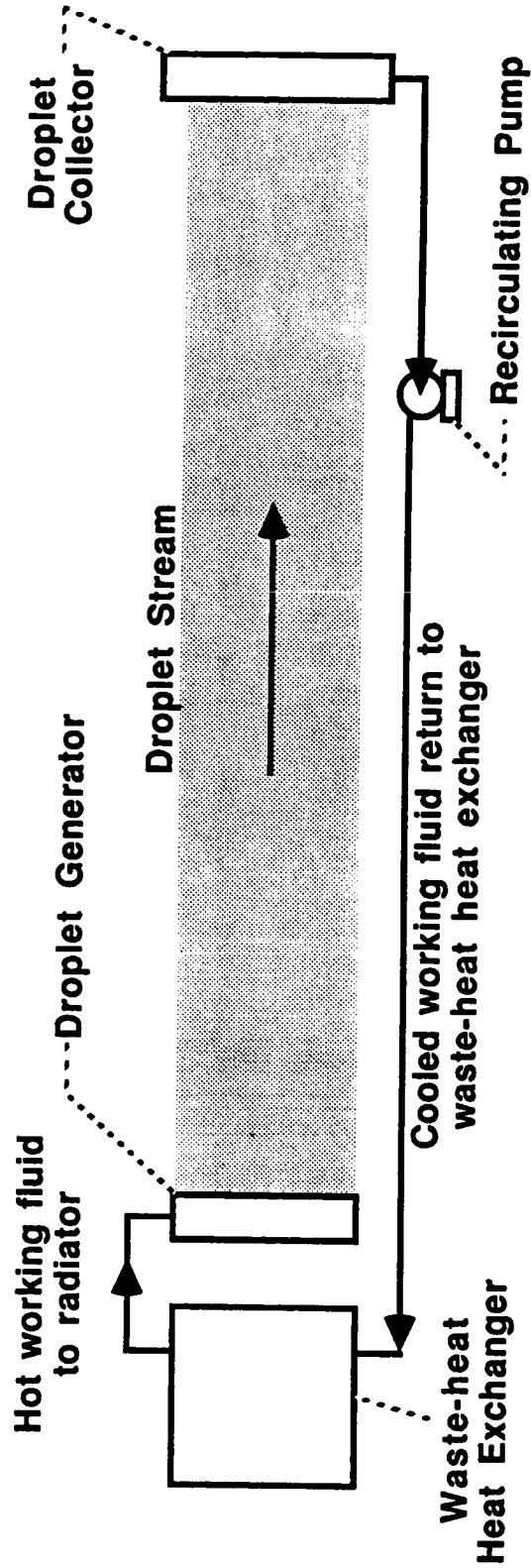
A test bed will be designed to Space Station architecture and will include: structure for mounting scaled complete modular radiators, electric power supply and test radiator instrumentation. The heat load for intermediate and high temperature test radiators would be provided electrically. Low temperature heat load could be Space Station provided. Operation of test radiators will be automated using a modular electronic control package installed in the Space Station. Test radiator systems will be installed and tested over their design temperature ranges for specific life periods. The testing-evaluation will be conducted in a combined space station environment which can't be duplicated on earth.



# TDMX 2132, Advanced Radiator Concepts

## Liquid Droplet Radiator

Radiative "fins" and "heat pipes" of conventional radiators replaced by multiple streams of uniform liquid droplets.



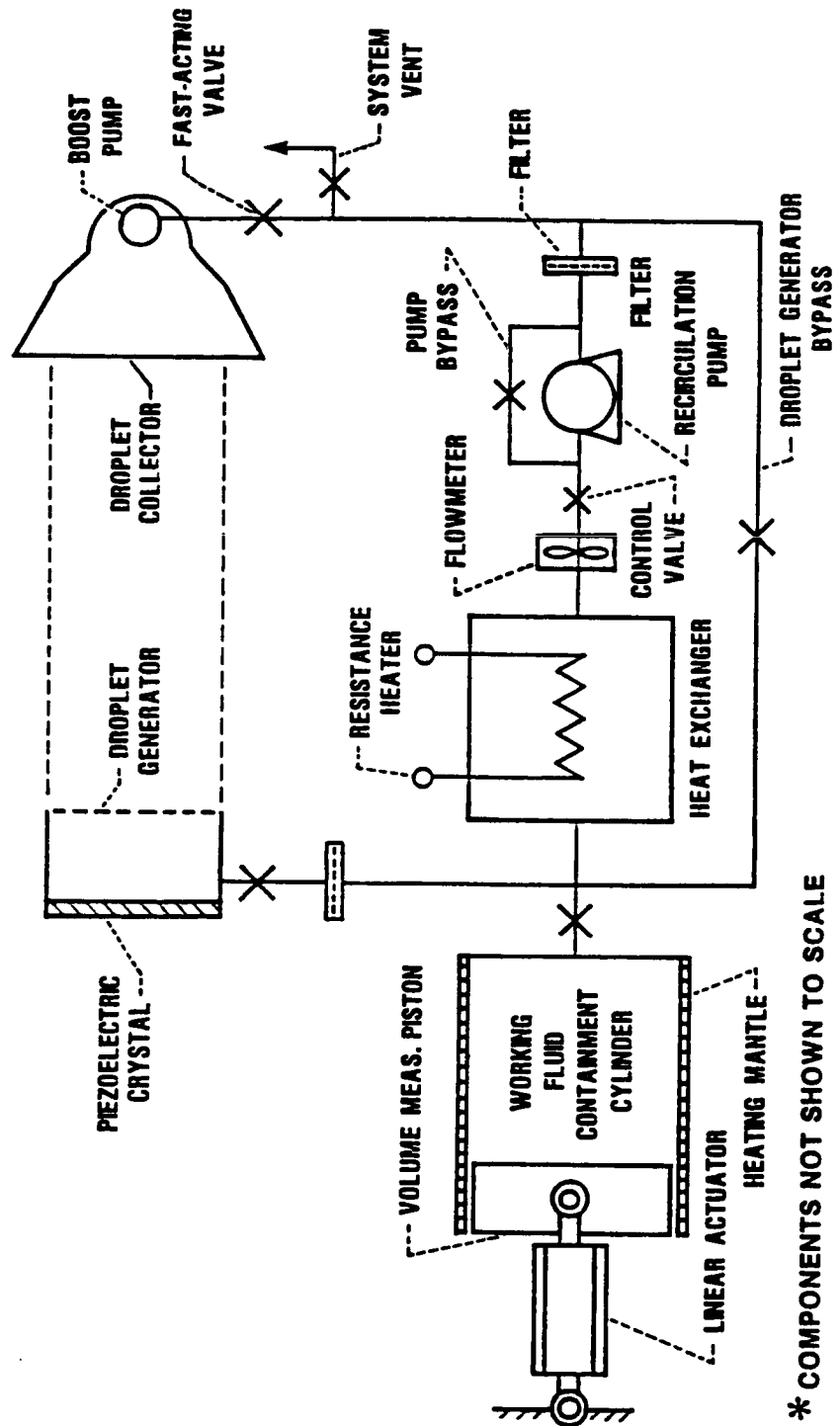


## LIQUID DROPLET RADIATOR SCHEMATIC

A schematic drawing of the liquid droplet radiator experimental apparatus is shown on the facing page chart. The proposed sub-scale experiment would simulate the operation of an advanced radiator for a space power conversion system. The working fluid, a typical diffusion pump oil, would be heated to various temperature levels by a variably-controlled electrical resistance heater. The heated fluid would be pumped through the droplet generator consisting of a multiple array of small orifices (25-100  $\mu\text{m}$ ). The Piezo-electric crystal mounted on the back manifold wall of the droplet generator provides the synchronizing frequency necessary to create droplets of 50-100  $\mu\text{m}$  droplets that reject heat to space by radiation and that are then gathered and coalesced in the droplet collector and recycled through the heat exchanger back to the droplet generator. The path length of the droplets from the generator to the collector will be about 3 m. The apparatus will contain various thermocouples, pressure transducers, flowmeters, displacement transducers, and other instrumentation to control and monitor system operation. The experiment will simulate heat rejection rates from about 500 to 1500 watts. The working fluid will be heated to about 350° K and will experience a temperature drop of about 10° K as a result of radiative heat rejection to space.



# Liquid Droplet Radiator Schematic





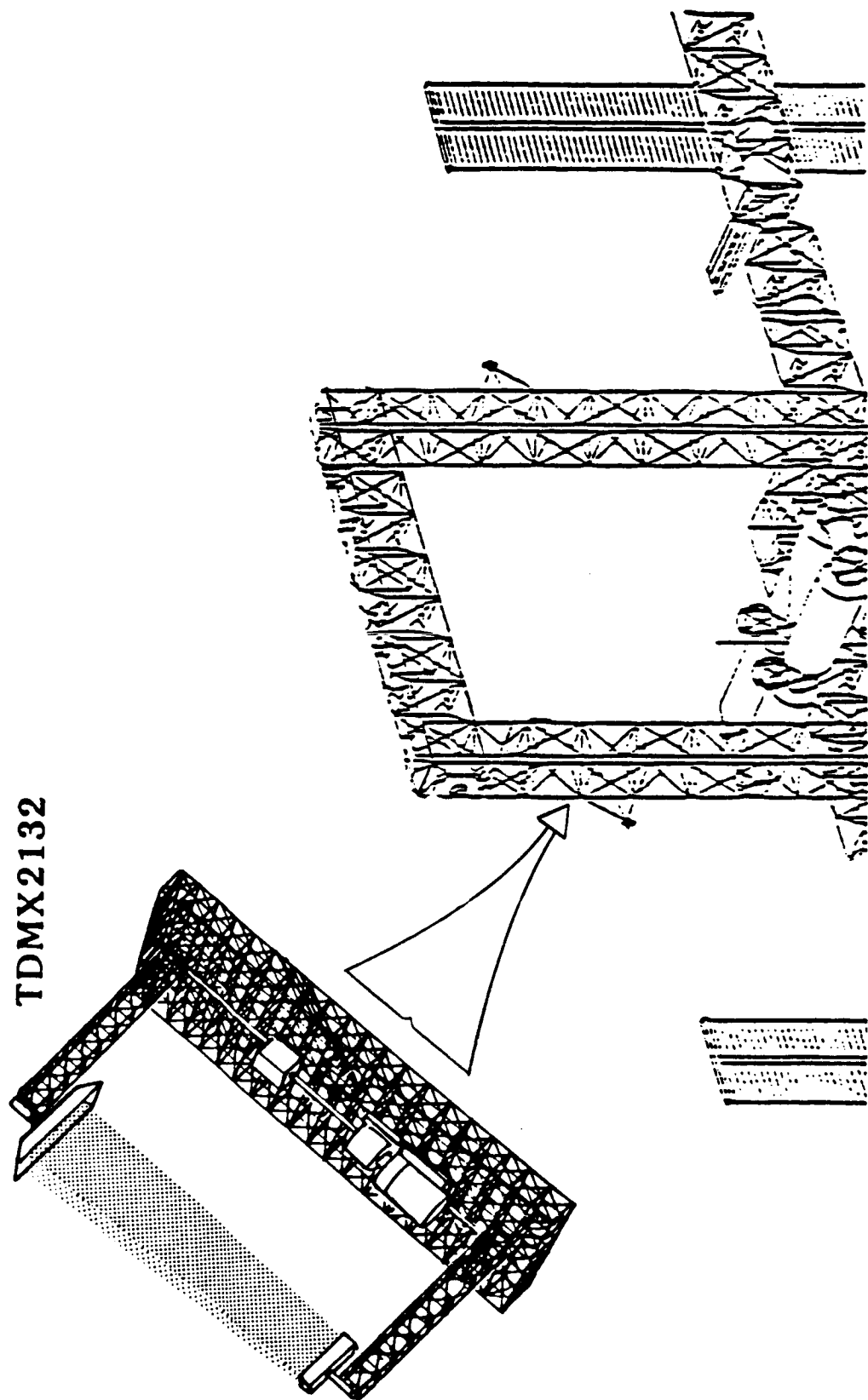
## POTENTIAL LIQUID DROPLET RADIATOR LOCATION

The location of the liquid droplet radiator is not critical; however, it would be prudent to locate it away from sensitive optical instruments/surfaces since contamination levels will be unknown until testing is accomplished. Also, rotational clearance is required so that an edge-to-the-sun orientation can be maintained. Envelope volume requirements are: length, 5m; width, 2m; and height, 2.5m. The preferred rotational axis is normal to, and centered on the 5m X 2m base. A potential location is shown on the facing page chart, the backside of the upper starboard keel.



# Potential Liquid Droplet Radiator Location

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## TDMX 2132      EQUIPMENT LIST

An equipment list including approximate dimensions and weights is provided on the facing page chart. Dimensions and weights of each component are initial rough estimates requiring a more detailed design analysis. Length is presumed to be the longest dimension of each component and width, next longest.



# TDMX 2132 Equipment List

<u>Component</u>	<u>Length (m)</u>	<u>Width (m)</u>	<u>Height (m)</u>	<u>Mass (kg)</u>
Test Bed Structural Platform	5.0	2.0	0.2	50
Droplet Generator Structural Support	2.0	0.2	0.1	5
Droplet Collector Structural Support	2.0	0.2	0.1	5
Droplet Generator	0.4	0.1	0.1	1
Droplet Collector	0.5	0.2	0.2	5
Boost (secondary) Pump	0.5	0.2 DIA	--	10
Circulation (primary) Pump	0.5	0.2 DIA	--	10
Heat Exchanger	0.3	0.2 DIA	--	10
Reservoir	0.5	0.2 DIA	--	10
Auxiliary Equipment	--	--	--	60
Working Fluid (silicone oil)	--	--	--	16
				<u>182</u>



## TDMX 2132      INSTRUMENTATION LIST

The chart on the facing page gives an initial estimate of the type and quantity of instrumentation required for the liquid droplet radiator experiment. Sensors compatible with the Space Station data acquisition system will be utilized whenever possible to minimize the amount of signal conditioning hardware required.

Peak sampling rate is once per second.



# **TDMX 2132                      Instrumentation**

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Temperature Transducers	21	Power Meters	9
Pressure Transducers	21	Current Meters	9
Mass Flow Meters	3	Voltage Meters	9
Frequency Meters	3	Accelerometers	9
Vacuum Transducers	3	Displacement Transducers	3
Speed Meters	6	Peak Sampling Rate	1/sec



## TDMX 2153 ADVANCED SOLAR DYNAMIC POWER

PI: THADDEUS S. MROZ/LeRC, (216) 433-6168

- **OBJECTIVE**

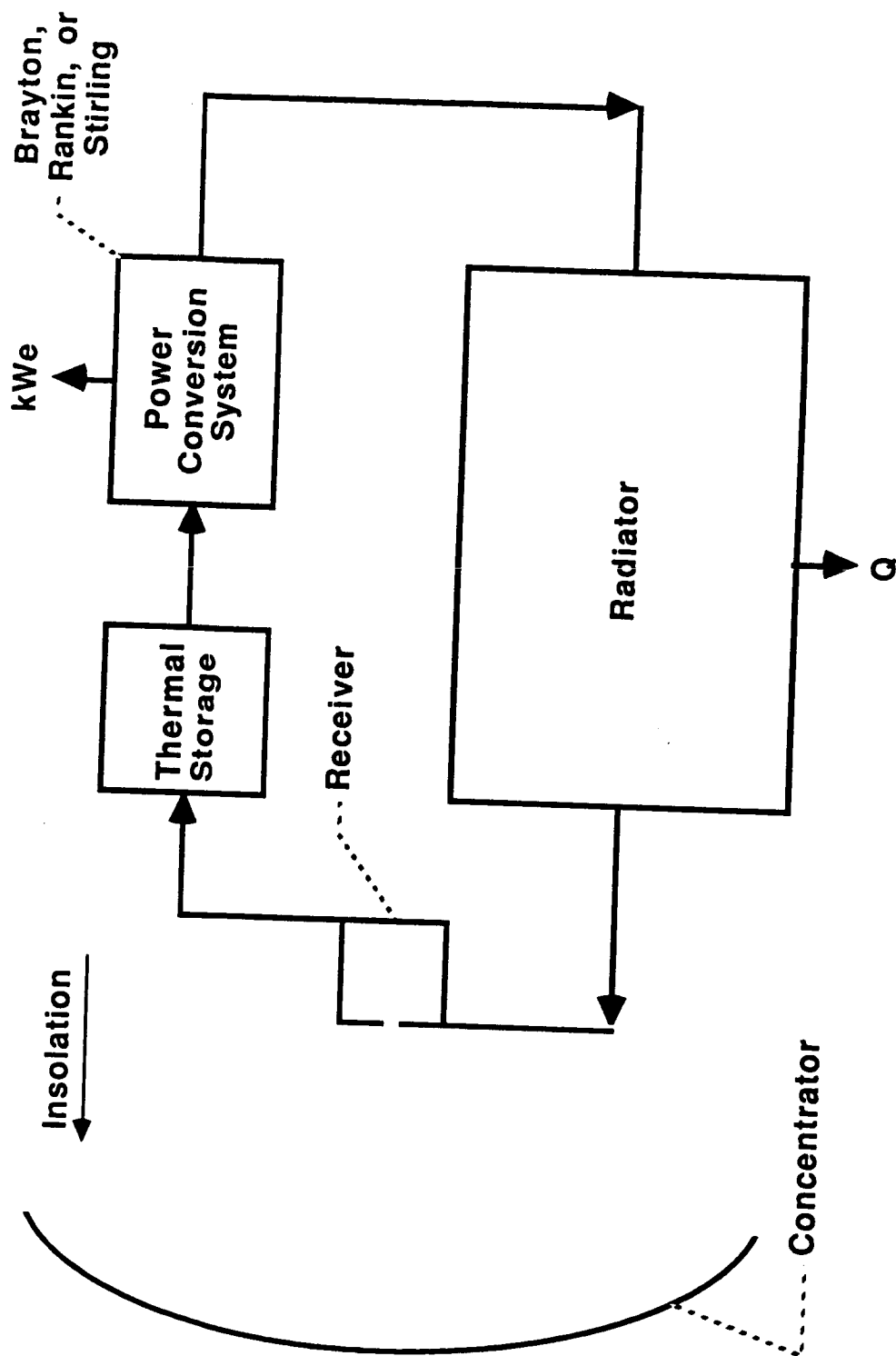
The objective of this effort is to provide a dedicated area on the Space Station for flight evaluation and test operation of candidate advanced solar dynamic power systems, subsystems, and components. The flight evaluation effort will be separate and apart from the operational power systems providing power to the Space Station.

- **DESCRIPTION**

As shown on the chart on the facing page, solar dynamic power systems consist of solar collectors, heat receivers, dynamic power conversion systems, and radiators. Several candidates for each component could be tested either individually or as part of a complete system. Solar collectors could be tested with different reflective surfaces (aluminum, silver) with different optical configurations (simple parabola, cassegrainian). Solar receivers could have different heat storage materials, different operating temperatures and different geometries. Various power conversion systems could be tested including Rankine, Brayton, and Stirling thermodynamic cycles. Space radiators tested could include tube and fin radiators, heat pipe radiators, and advanced radiator concepts. A major objective of the facility would be to perform confirmation tests of a variety of advanced components and configurations that have shown promise during ground testing.



# **TDMX 2153, Advanced Solar Dynamic Power**





## ADVANCED SOLAR DYNAMIC

### POWER SYSTEM SCHEMATIC (20KWE)

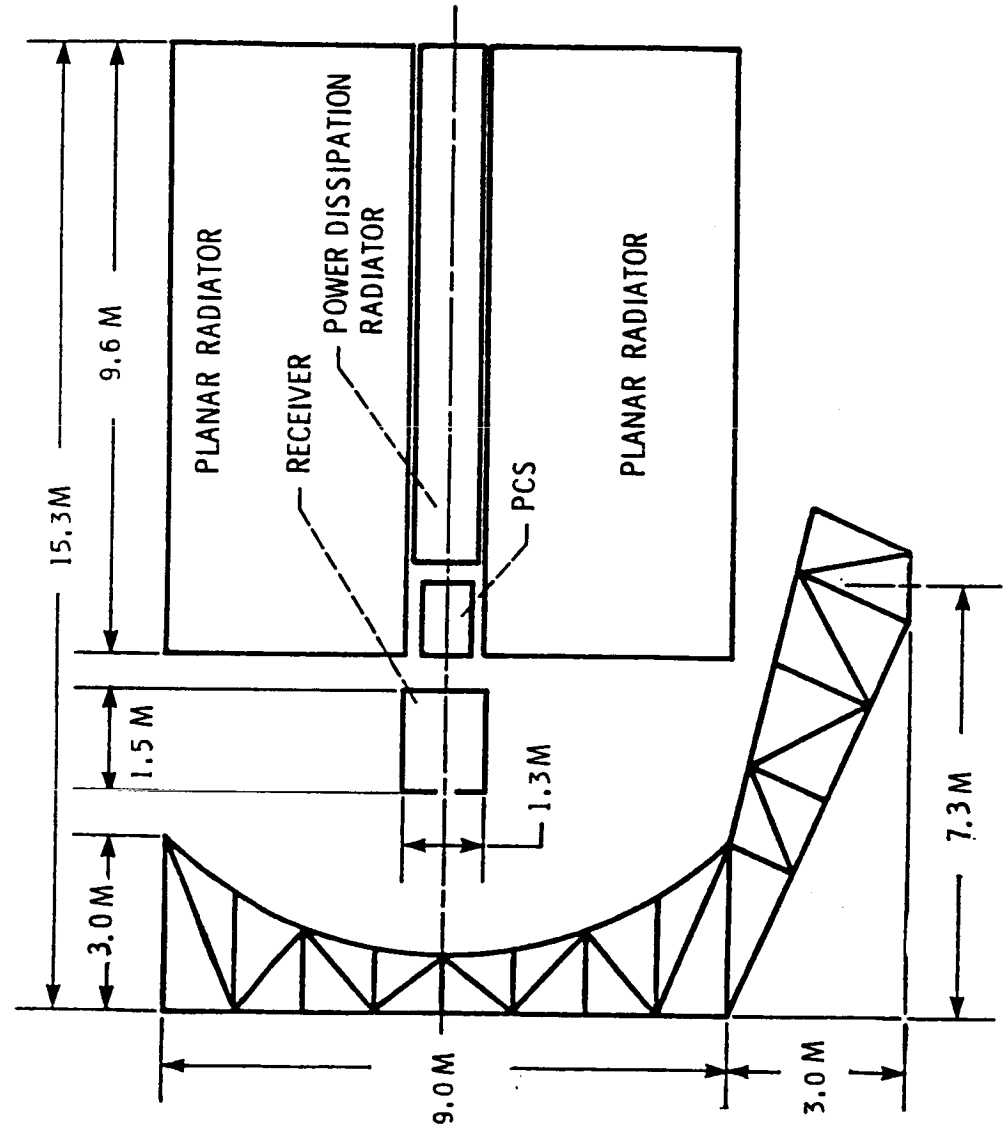
A sketch and overall dimensions of an advanced solar dynamic power system (ASDPS), sized for 20 kWe, is shown on the facing page chart. For this system, the PCS (power conversion system) was assumed to use a Brayton prime mover. The envelope volume of the ASDPS is assumed to be a cylinder with a diameter of 9.0m and an overall length of 15.3m plus the volume of the pedestal mount. Total weight is estimated to be 1240 kg.

Not shown in the figure, but necessary for an ASDPS are the following:

- Pointing system
- PCS controller
- Power management and distribution system
- Ducting or piping
- Data acquisition and transmission



# Advanced Solar Dynamic Power System Schematic (20kwe)





## POTENTIAL ASDPS LOCATION

As shown on the chart on the facing page, the port end of the upper boom is a potential location for the advanced solar dynamic power system (ASDPS) test facility. Mounting requirements are similar to those of the baseline power system for the Space Station (SS); i.e., a clear, unobstructed view of the sun. This means a pointing system, with two degrees of freedom similar to that provided by the alpha and beta joints on the SS power boom, must be incorporated into the mount. The payload pointing system (PPS) element of the proposed attached payload accommodations equipment (APAE) appears more than capable.

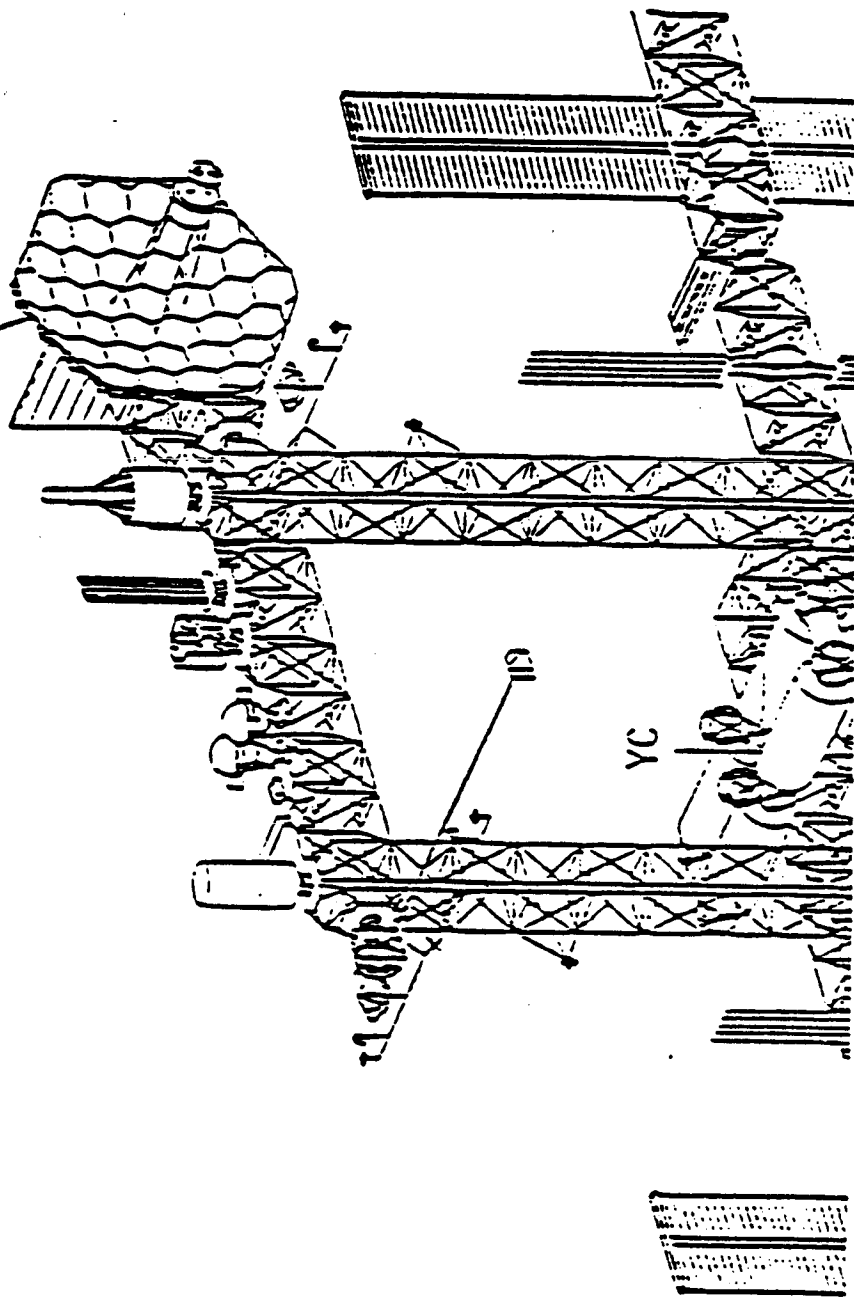
If the ASDPS could be located on an end of the SS power boom, the pointing system for the ASDPS could be reduced to a single degree of freedom beta joint since the power boom already has the requisite alpha joint.



# Potential ASDPS Location

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TDMX 2153  
Solar Dynamic Power





## TDMX 2153 EQUIPMENT LIST

An equipment list, including preliminary component masses and total mass for a 20kWe advanced solar dynamic power system projected to the 1990s time period is provided on the facing page chart. Mass calculations assumed an advanced high temperature ( $\sim 1100^\circ\text{K}$ ) Brayton prime mover and are initial rough estimates requiring a more detailed design analysis. Total system mass may be reduced by advanced materials, such as ceramics, or advanced heatpipe technology.



# TDMX 2153 Equipment List

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<u>COMPONENT</u>	<u>WEIGHT, kg</u>
Collector & Truss Structure	136
Receiver & Thermal Storage	318
Power Conversion System	82
Recuperator	159
Radiator	367
Structure	64
Power Dissipation Radiator	50
Pointing System, Controls, Pip[ing, Data, etc	64
<hr/>	
Total	1240 kg



## TDMX 2153 INSTRUMENTATION LIST

The advanced solar dynamic power system (ASDPS) will be instrumented in such a manner as to effectively monitor performance, performance degradation, and possibly impending component failure. The instrumentation will provide operational and diagnostic measurements. The chart on the facing page gives an initial estimate of the type and quantity of instrumentation required for an ASDPS. This list assumes a Brayton prime mover. Sensors compatible with the Space Station data acquisition system will be utilized when ever possible to minimize the amount of signal conditioning hardware required.

The rate at which the listed data is scanned is a function of the test phase. During startup, a continuous scanning mode is needed; i.e., the total data set scanned once per second. During steady state operation, the total data set need not be scanned oftener than once every 30 minutes, except for a few critical measurements which need continuous scanning.



# **TDMX 2153 Instrumentation List**

---

<b>Temperature Transducer</b>	<b>135</b>
<b>Pressure Transducer</b>	<b>18</b>
<b>Mass Flow Meter</b>	<b>3</b>
<b>Speed Meter</b>	<b>3</b>
<b>Power Meter</b>	<b>3</b>
<b>Amperage Meter</b>	<b>3</b>
<b>Voltage Meter</b>	<b>3</b>
<b>Accelerometer</b>	<b>24</b>
<b>Peak Sampling Rate</b>	<b>1/SEC</b>



## TDMX 2311

### LONG-TERM CRYOGENIC FLUID STORAGE

PI: JOHN C. AYDELOTT/LeRC, (216) 433-2472

- OBJECTIVE

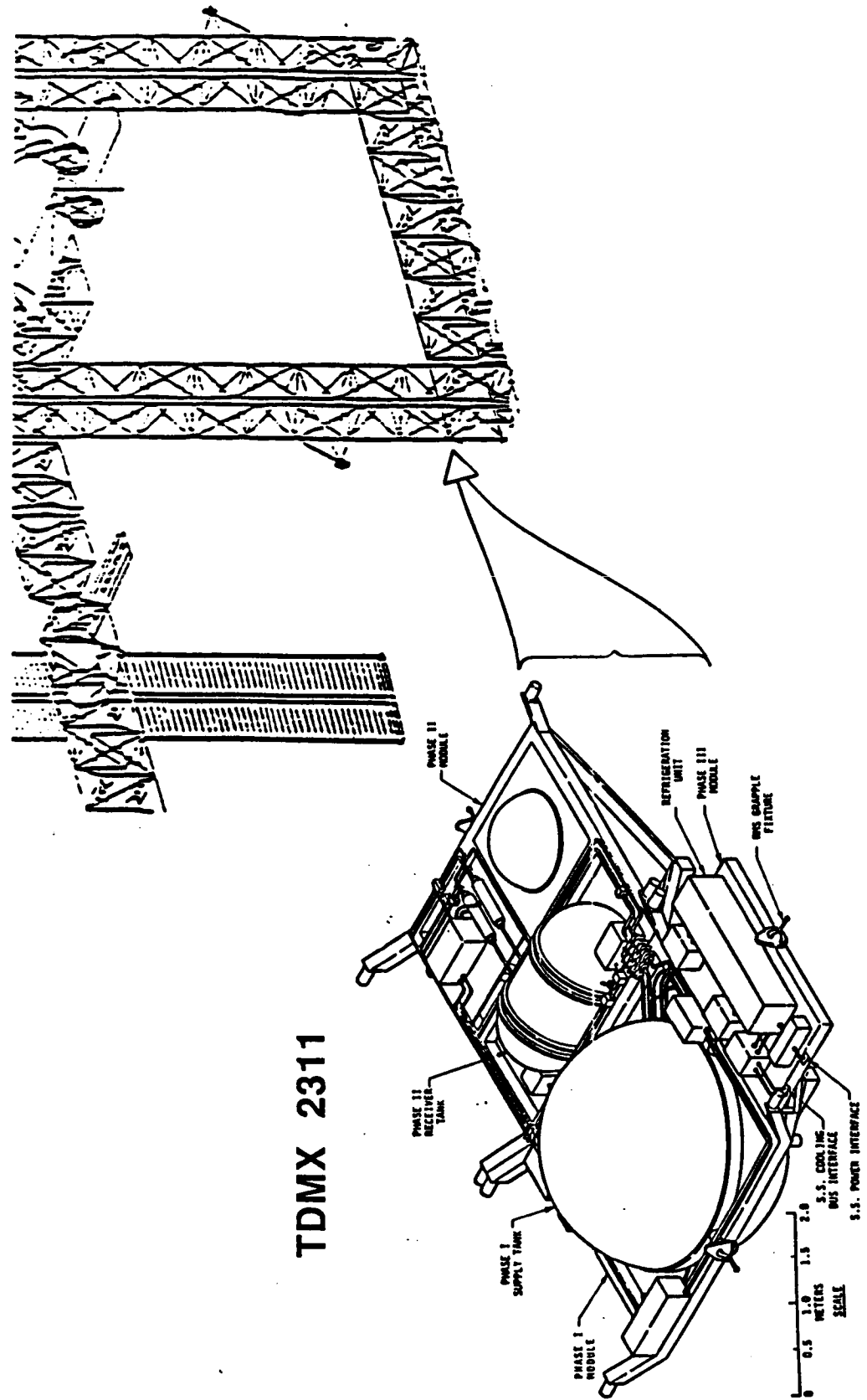
This experiment will demonstrate long-term storage, including refrigeration system performance, and transfer of cryogenic fluids in an on-orbit environment. Various technologies utilized in long-term storage and transfer of cryogenics will be tested and evaluated. These technologies range from basic passive technologies such as thick multi-layer insulation blankets, to active refrigeration system.

- DESCRIPTION

The facing page chart shows the test article and the preferred location adjacent to the proposed OTV service bay so that it will be subjected to a similar environment. The experiment consists of three phases. Phase I will test basic passive technologies utilized in long-term cryogenic storage. A 6.46 m<sup>3</sup> tank will be mounted to the Space Station, and thermal performance data will be measured for a period of two years. Phase II will demonstrate cryogenic fluid transfer technologies. The test article will be reconfigured on-orbit by adding a receiver tank and other necessary hardware. Phase II experimentation will be performed for a period of one year. Phase III will demonstrate active refrigeration technology. A pallet containing an active refrigeration system will be delivered to the Space Station and attached to the test article. The refrigeration system will be tested for a period of at least one year.



# TDMX 2311, Long-Term Cryogenic Fluid Storage



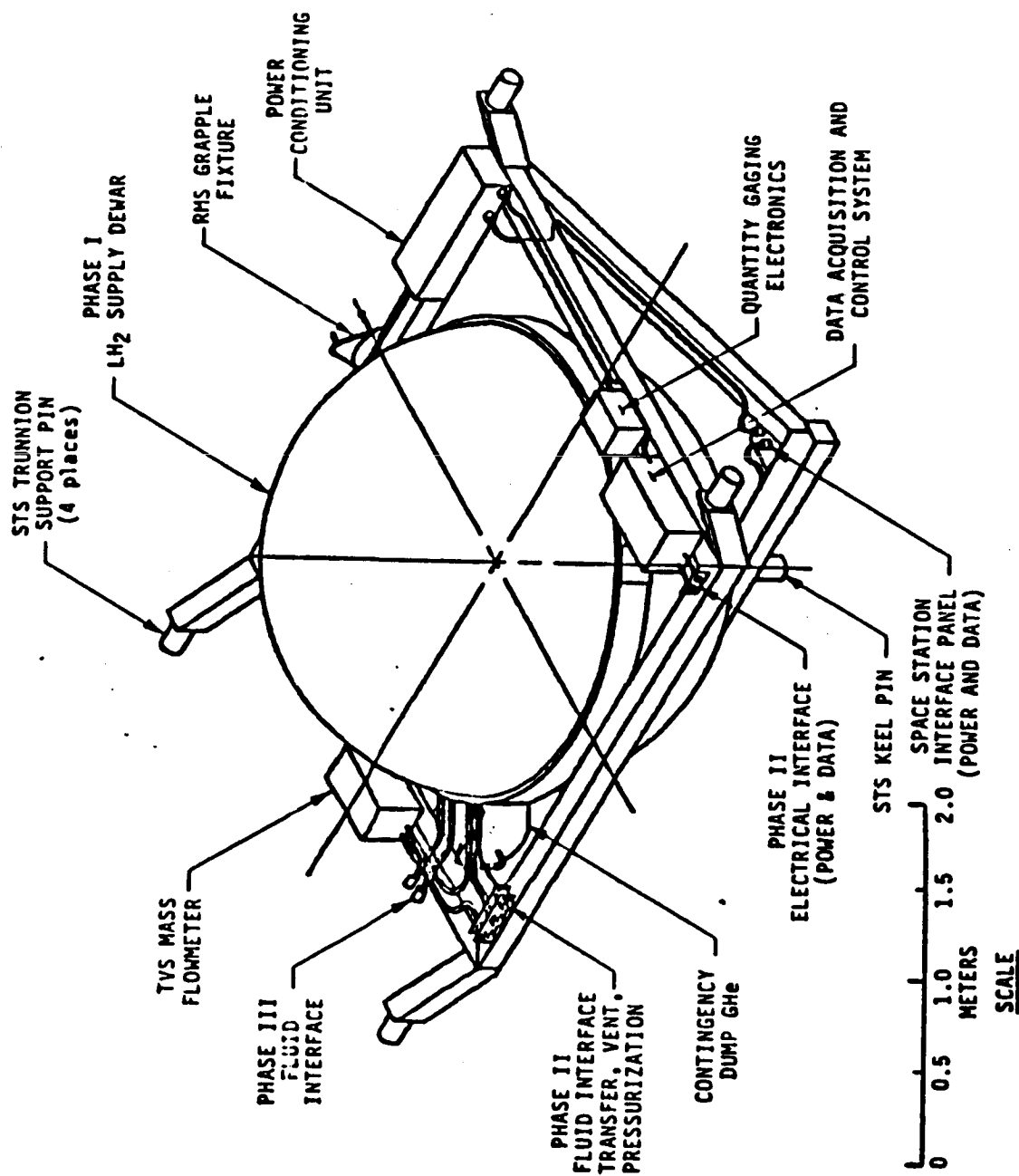


## **PHASE I EXPERIMENT CONFIGURATION**

Phase I of the experiment is designed to demonstrate basic passive thermal control technologies. In addition, hardware necessary for interfacing with the Space Station as well as with Phases II and III is included. An isometric view of the Phase I configuration is shown on the facing page chart. The configuration consists of a 6.46 m<sup>3</sup> LH<sub>2</sub> supply dewar mounted in an aluminum support structure. Standard trunion pin mounts are used as framework mounting interface for Space Shuttle launch. Both keel and payload bay bridge fitting trunnions are employed. Fluid and electrical interface panels are provided for Space Station and Phase II and III interfaces. The Phase I test article is attached to the Space Station structure via the attached payload accommodation equipment.



# Phase I Experiment Configuration





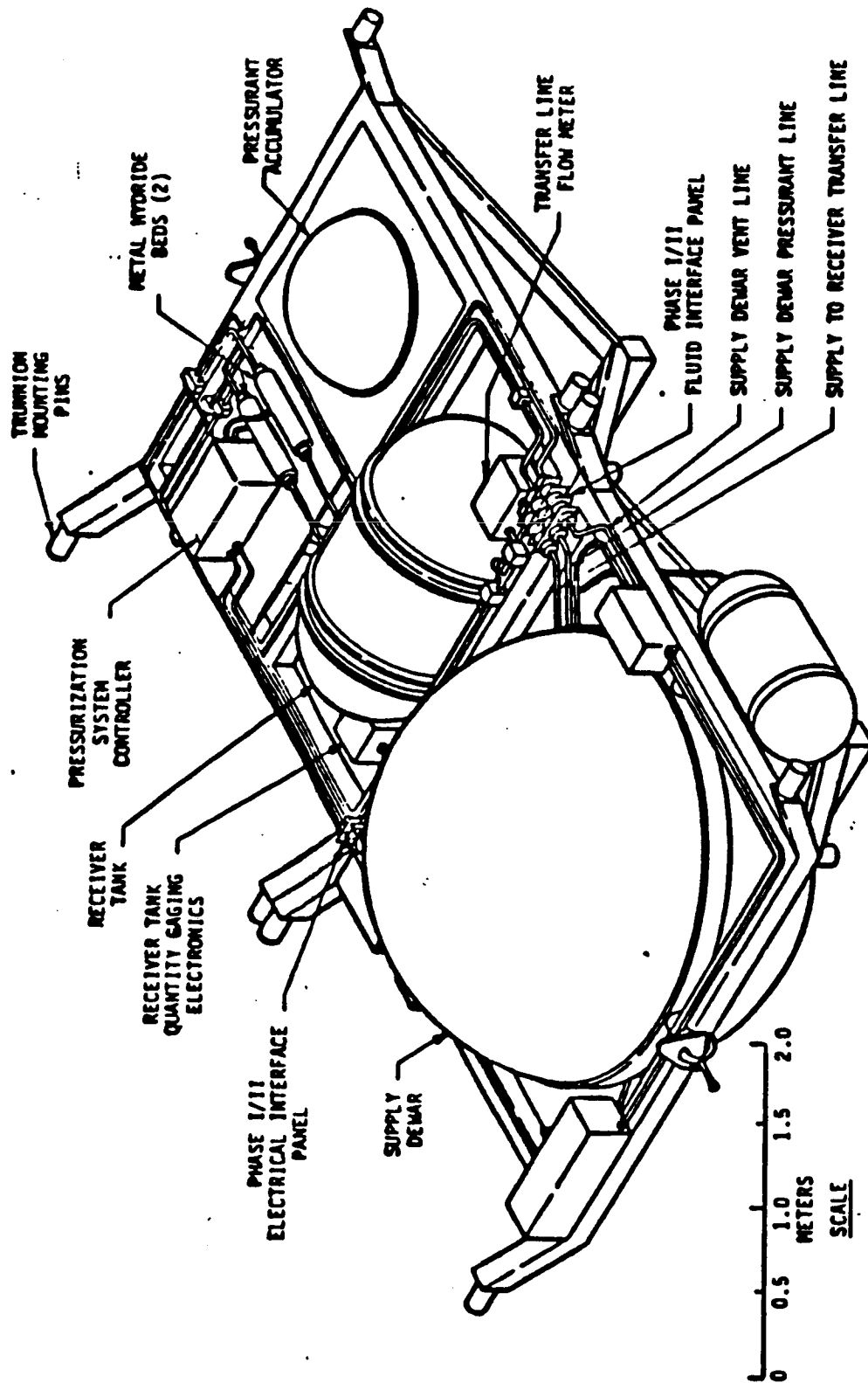
## PHASE II EXPERIMENT CONFIGURATION

Phase II of the experiment is designed to demonstrate and evaluate low-g fluid transfer technologies. In addition, thermal performance of a soft outer shell receiver dewar will be evaluated. An isometric view of the Phase II experiment configuration is presented on the facing page chart. The test article will be reconfigured on-orbit by the addition of the Phase II module containing the receiver tank and pressurization system. Fluid transfer operations will then be performed to evaluate the hardware and techniques necessary to achieve low-g fluid transfer. The receiver tank in the Phase II module will be flown up to the Space Station empty, eliminating many flight safety issues and the requirement for ground purge of the soft outer shell receiver tank. This reduces the cost and complexity of the Phase II module.

The Phase II receiver tank is a  $1.27 \text{ m}^3$  soft outer shell dewar. A transfer line wrapped in multi-layer insulation (MLI) connects the supply and receiver tanks for fluid transfer. A line providing gas pressurant from the Phase II module pressurization system is connected to the supply dewar. Supply dewar vent gas is routed to a boiloff collection system on the Phase II module, where the gas is stored and pressurized utilizing a passive metal hydride compressor to provide pressurant for fluid transfer operations. The pressurant is stored in a 3.4 MPa (500 psia) spherical aluminum pressure vessel.



# Phase II Experiment Configuration





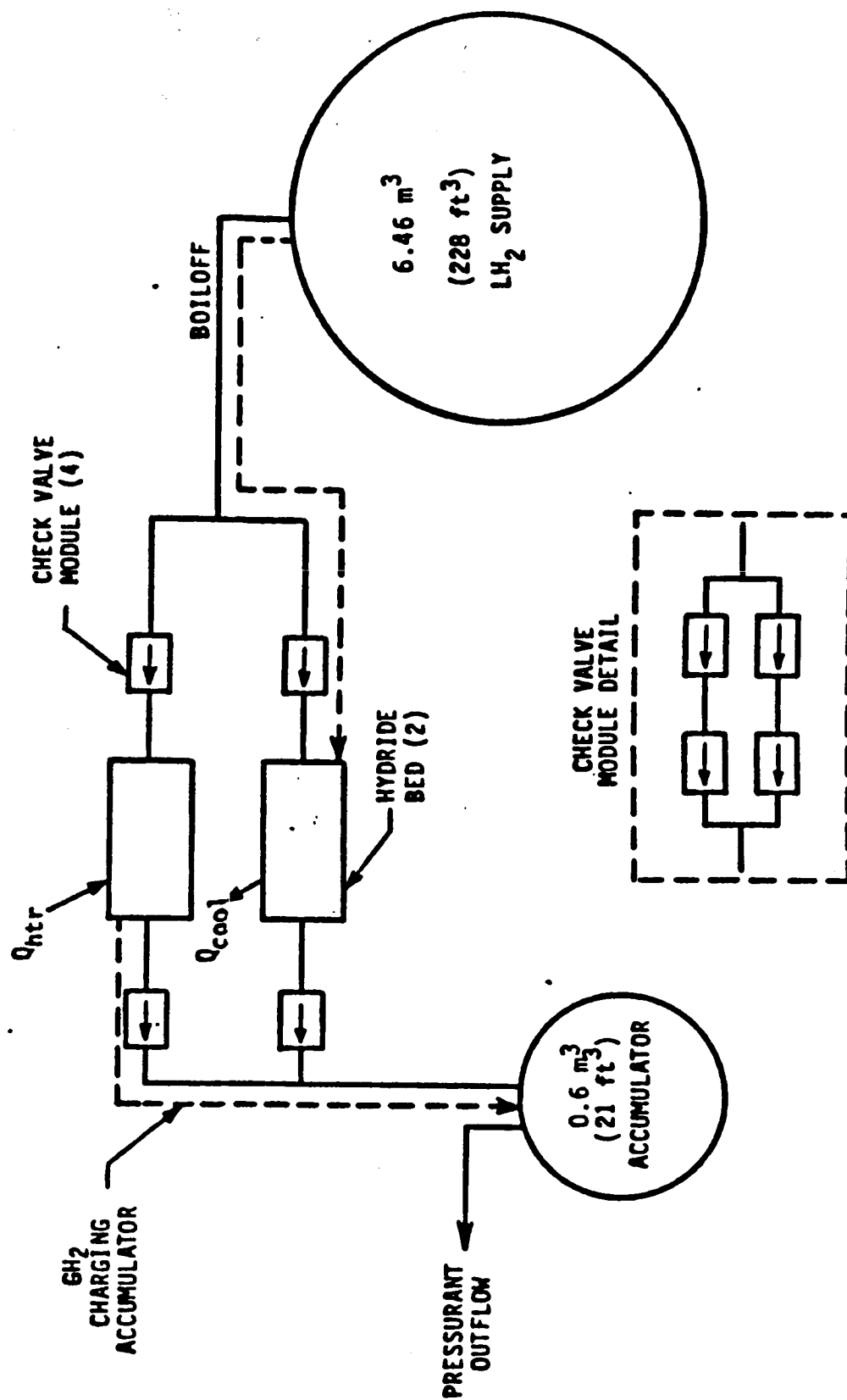
## PRESSURIZATION SYSTEM SCHEMATIC

The chart on the facing page shows a schematic of the passive metal hydride compressor system. As a hydride bed is heated,  $H_2$  is expelled. Conversely as it is cooled,  $H_2$  is absorbed. This principle allows control of the system to be achieved utilizing check valves rather than solenoid operated valves. As depicted in the figure, a check valve module is located at each end of both hydride beds. Each module consists of four individual check valves in a series-parallel arrangement. This allows for proper valve operation in the event of a check valve failure in either the closed or open mode.

As illustrated on the facing page chart, the lower hydride bed is being cooled. This causes it to absorb  $H_2$  which lowers the pressure within the bed, causing the check valve between it and the supply dewar to open, allowing boiloff  $H_2$  to enter the hydride bed and, in turn, be absorbed. The check valve between the accumulator and lower hydride bed remains closed because the accumulator pressure is higher than that of the lower hydride bed. The upper hydride bed, which was previously charged with  $H_2$ , is being heated, causing it to expell  $H_2$  which increases the pressure within the bed. This increase in pressure keeps the check valve between the upper bed and the supply dewar closed. When the upper hydride bed pressure becomes higher than in the accumulator, the check valve between them opens and  $H_2$  is transferred to the accumulator. This process continues until the upper hydride bed is depleted and the lower hydride bed is charged. At this point, the heating and cooling cycles are reversed. This process continues until the accumulator is charged to 3.4 MPa (500 psia). Thus, the passive metal hydride compressor system is controlled merely by alternately heating and cooling the hydride beds.



# Pressurization System Schematic





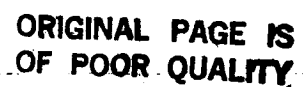
## FLUID TRANSFER SYSTEM SCHEMATIC

Prior to a transfer operation, transfer line and receiver tank cooldown will be performed. Pressurant flows from the accumulator into the supply tank, expelling liquid into the transfer line. Initially, the transfer line is warm, and boiling occurs within the line injecting vapor into the receiver tank. Once the transfer line has been cooled, cooldown of the receiver tank begins. Tank cooldown consists of repeated cycles consisting of charging the tank with cryogen, holding the tank in a no-vent state while the cryogen is superheating, then venting the superheated vapor. After the fluid is injected and superheated, the vent valve is opened and the fluid is vented.

After tank cooldown has occurred, fluid will be transferred from the supply tank to the receiver tank. This process is depicted in the chart on the facing page. Pressurant gas flows from the accumulator to the supply tank, expelling fluid through the transfer line. The fluid passes through the mass flowmeter, and enters the receiver tank through the fill line. It should be noted that the system is configured to flow cryogen from the receiver tank back to the supply dewar by pressurizing the receiver tank and backflowing through the transfer line. Valves and lines have been designed such that liquid will flow through the mass flowmeter in the same direction, regardless of direction fluid transfer.



100





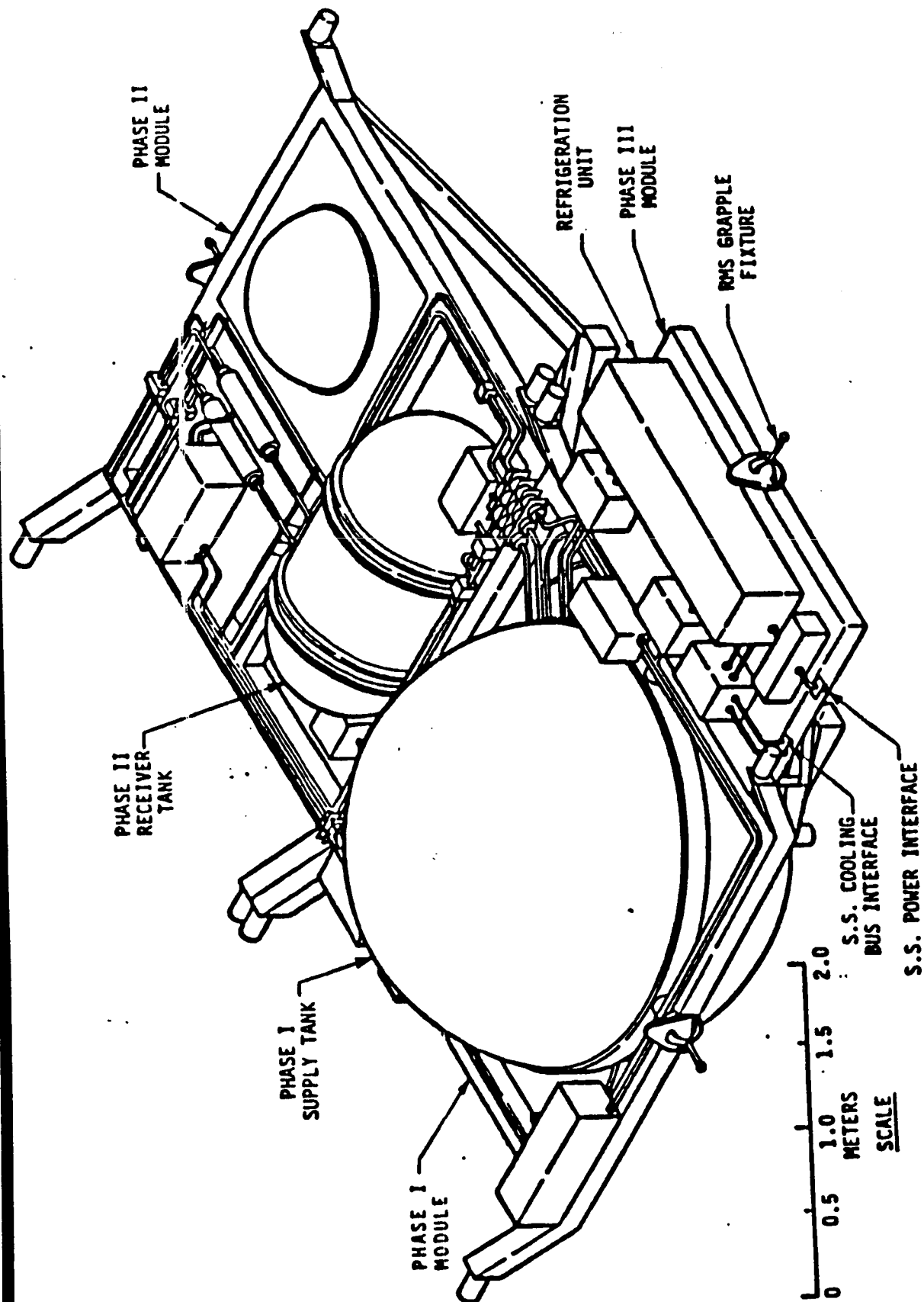
## PHASE III EXPERIMENT CONFIGURATION

An isometric view of the Phase III configuration is presented on the facing page chart. The Phase III module is attached to the side of the Phase I module, and interfaced with the Phase I electrical, data, and fluid systems.

Phase III of the experiment will demonstrate active refrigeration technologies. In Phase III, a refrigeration unit will be integrated with the Phase I supply dewar to reduce or eliminate cryogen boil-off. Long lifetime, flight qualified refrigerators are the least developed of all technologies that are to be included in this TDMX, yet they also have the most technology development programs currently underway. These development programs encompass a wide variety of refrigerator types from closed-gas cycles, such as the Stirling and Brayton cycles, to gas absorption and magnetic refrigerators. Several of these refrigerators, most notably the Vuilleumier and several Stirling cycle machines, have demonstrated several thousands of hours of continuous operation, including one Stirling type flown on the DOD P-78-1 Satellite in 1979 (Phillips Rhombic Drive Stirling). However, it is still unclear as to which particular unit will prove best suited for use on Phase III. Thus, it was decided to design the Phase III hardware in a "generic" manner capable of interfacing with several types of refrigeration units with minimal changes.



# Phase III Experiment Configuration





## REFRIGERATION SYSTEM SCHEMATIC

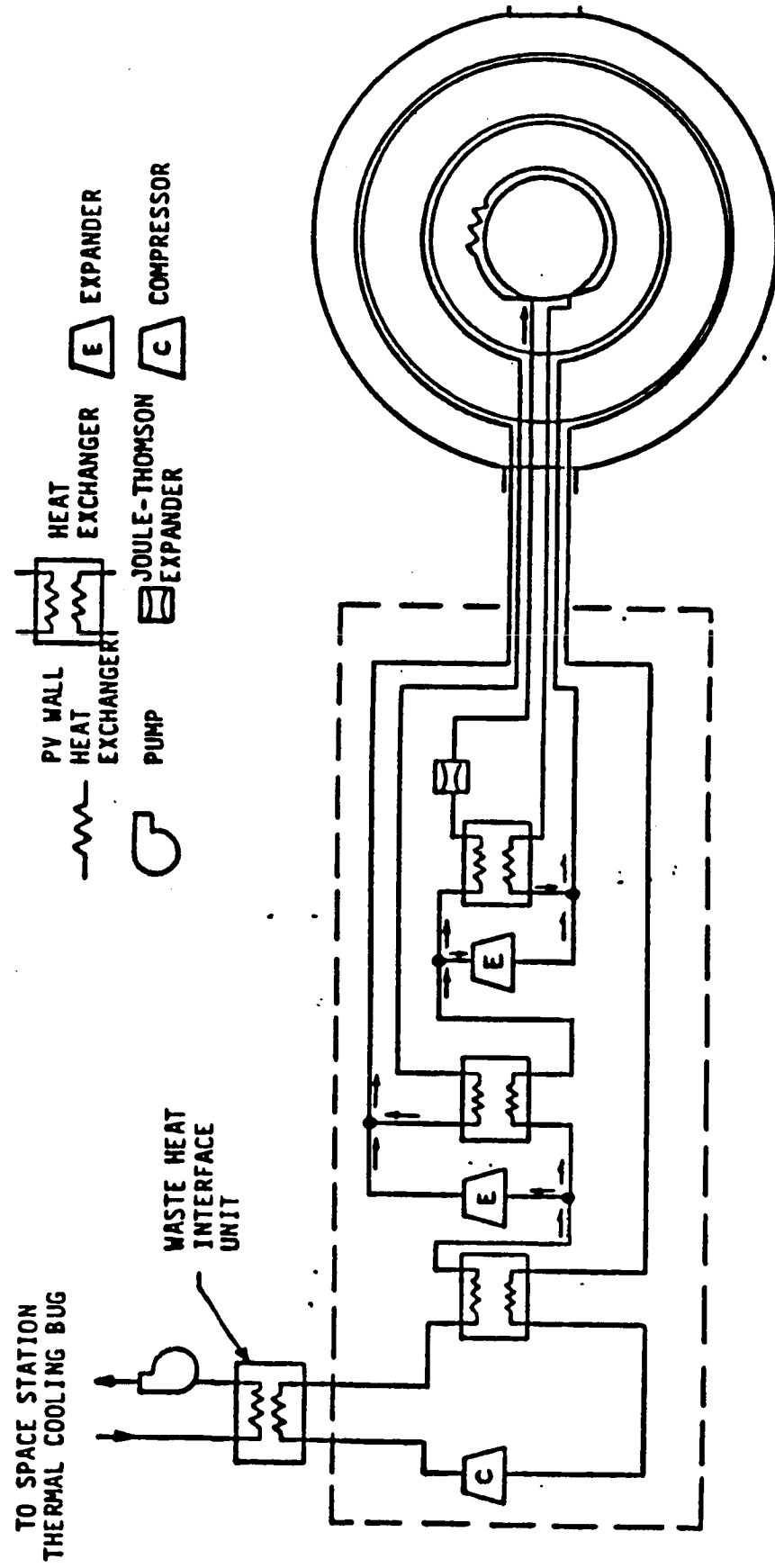
A fluid flow schematic of the Phase III module interfaced with the Phase I thermodynamic vent system (TVS) is presented on the facing page chart. A Stirling cycle refrigerator with hot and cold "fingers" is depicted since its high level of development makes it a likely candidate for use in Phase III.

Cooling of the Phase I dewar will be accomplished by passing coolant through fluid lines that run parallel to its TVS. This allows the refrigerator to provide all or almost all of the cooling required by the supply dewar. Thus, a refrigerator system that is sized specifically for this experiment is not required, allowing use of more economical "off the shelf" hardware. The coolant interface unit (CIU) will circulate fluid from the cold side of the refrigerator through the TVS. Gaseous helium (GHe) will be utilized as the heat transfer fluid due to its inherent safety, superior heat transfer characteristics, and its low condensation temperature. Refrigerators that do not circulate cold working fluid, such as the Stirling and Magnetic refrigerators, would use a CIU that has a cryogen circulator to circulate fluid around the cold side of the refrigerator. In other systems that do circulate refrigeration fluid, such as an absorption refrigerator, the CIU would contain a circulator in conjunction with a heat exchanger to interface the refrigerator coolant and the GHe TVS coolant.

The waste heat interface unit transfers the refrigerator waste heat from the refrigerator hot side to the Space Station thermal cooling bus. Since the Phase III power requirements (approximately 2.5 kW) are much higher than for the previous phases of this experiment, a separate power conditioning unit is included in the Phase III module.



# Refrigeration System Schematic





## **TDMX 2311 EQUIPMENT LIST**

An equipment list for the Long-Term Cryogenic Fluid Storage experiment, including approximate dimensions and weights, is provided on the facing page chart. Dimensions and weights of each component are preliminary design estimates requiring a detailed design update.



# TDMX 2311 Equipment List

EQUIPMENT	LENGTH (in)	WIDTH or DIA (in)	HEIGHT (in)	WEIGHT (kg)
<u>Phase I Hardware</u>				
Supply Dewar	105	105	--	900
Data Acquisition & Control Interface Panel	30	12	20	100
Support Structure	36	24	12	45
	150	180	110	900
<u>Additional Phase II Hardware</u>				
Receiver Tank	84	48	--	130
Pressurization System	60	48	48	100
Support Structure	92	180	80	200
<u>Additional Phase II Hardware</u>				
Refrigeration System	92	24	24	550
Support Structure	92	24	12	250



## **TDMX 2311 INSTRUMENTATION LIST**

The chart on the facing page gives a preliminary design estimate of the type and quantity of instrumentation required for the Long-Term Cryogenic Fluid Storage experiment. Phase II instrumentation is in addition to that listed for Phase I and Phase III instrumentation is in addition to that listed for Phases I and II.

The data sampling rate is a function of the test phase. Except during cryogenic fluid transfer operations when the total data set must be scanned once per second, the total data set need not be scanned oftener than 10 times per hour.



# TDMX 2311 Instrumentation List

---

	<u>PHASE I</u>	<u>PHASE II</u>	<u>PHASE III</u>
TEMPERATURE TRANSDUCER (11-333° K)	19	31	42
PRESSURE TRANSDUCER (0-345 KPa)	1	3	3
VACUUM TRANSDUCER (10 <sup>-4</sup> - 10 <sup>-9</sup> TORR)	1	1	1
MASS FLOW METER (0-0.045 Kg/Hr)	1	2	3
RF QUANTITY GAGING SYSTEM	1	2	2
VALVE STATUS (OPEN/CLOSED)	4	22	22
POWER METER (0 - 2.5 KW)	-	-	1
PEAK SAMPLING RATE	10/HR	1/SEC	10/HR

NOTE: ONLY PRIMARY INSTRUMENTATION SET LISTED - DUPLICATE, BACKUP SET ALSO  
REQUIRED.



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# **Marshall Space Flight Center Proposed Technology Development Mission Experiments**

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## TDMX 2561 SATELLITE SERVICING AND REFURBISHING

- OBJECTIVE

Demonstrate and verify the capability to refurbish and resupply LEO operational satellites from the Space Station. An in-orbit satellite whose nominal mission is complete will be used. (GRO is a possibility). When the TDMX is complete, the satellite will be returned to its orbit.

- DESCRIPTION

The satellite is retrieved from its orbit and brought to the Space Station by the OMV. Alternately, the satellite flies to the Space Station. When in Space Station proximity, the satellite is retrieved and berthed in the satellite servicing facility. Servicing will include ORU changeout, refueling and other repair/refurbishment. The servicing operations may be actually needed or may be simulated. The facing page figure identifies these operations and shows a satellite being serviced at the Space Station.

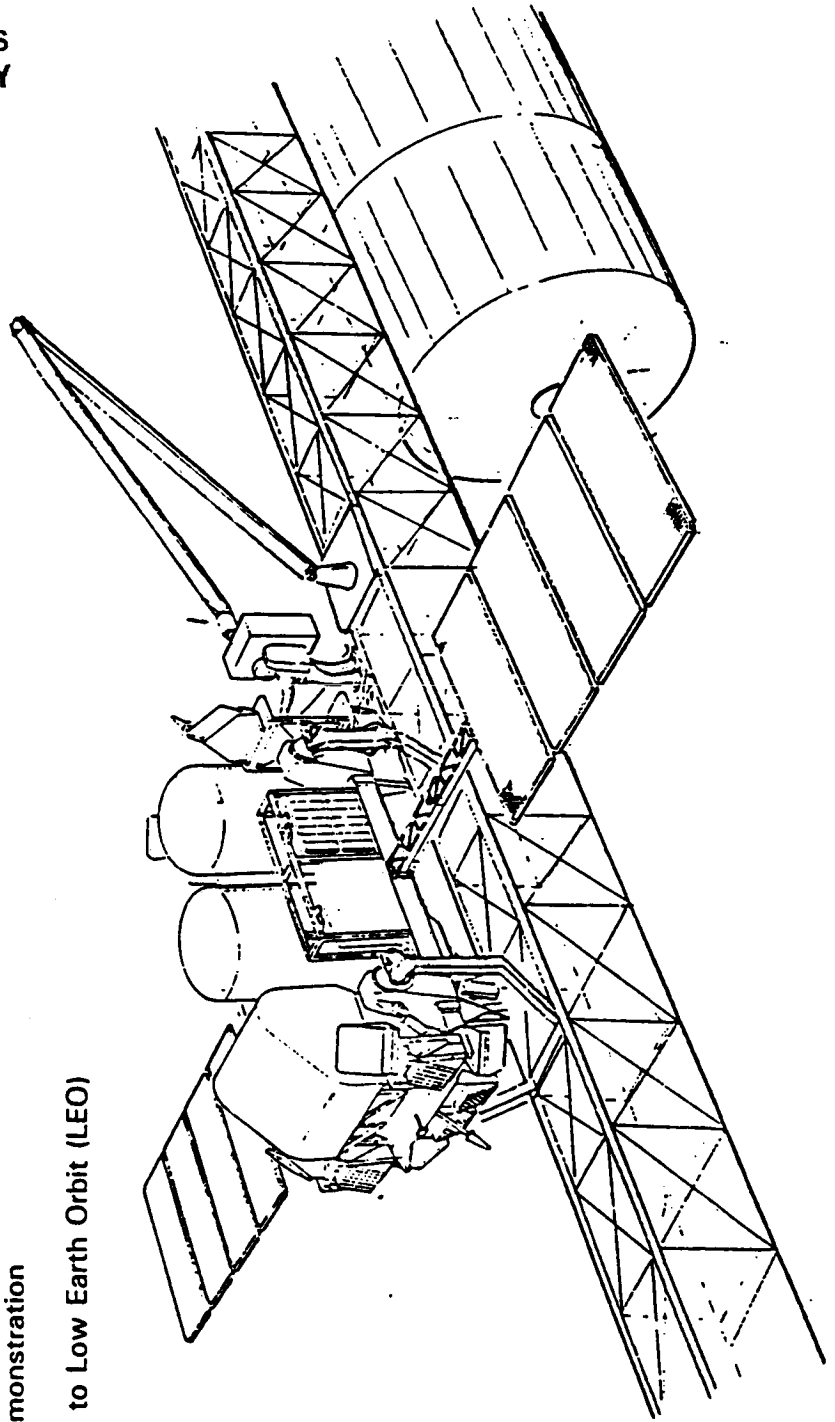


# TDMX 2561 SATELLITE SERVICING AND REFURBISHING

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1. Orbital Maneuvering Vehicle (OMV) Rendezvous with Gamma Ray Observatory (GRO)
2. OMV Docks to GRO and "Flies" to Space Station
3. Mobile Manipulator System (MMS) Positions GRO for Attachment to Space Station Satellite Servicing Facility
4. Demate OMV FOR Servicing and Storage
5. Changeout Orbital Replacement Units (ORUs)
6. Remote Fueling Demonstration
7. OMV Returns GRO to Low Earth Orbit (LEO)

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## EQUIPMENT LIST FOR TDMX 2561 AND 2562

Since these TDMX's are meant to verify the operational capability of the Space Station to service satellites in orbit, almost all of the equipment used will be space station provided. All unique equipment that may be needed to perform these TDMX's will be dictated by the requirements to perform specific tests and/or checkout procedures for the satellites being serviced.

This list shows the space station equipment that needs to be reserved when performing the TDMX's. The list also shows the time frame during the TDMX in which the equipment may be used.



# Equipment List for TDMX 2561 & 2562

EQUIPMENT	2562 Satellite Maintenance and Repair	2561 Satellite Servicing and Refurbishing
MRMS Controls and Displays	S,O,C	S,O,C
OMV Controls and Displays	O	O
EVA Monitor and Displays	O,C	O,C
C&W Monitor and Displays	O,C	O,C
Experiment Monitor and Displays	O	O
Ground Comm and Displays	S,O,C	S,O,C
Lighting Controls	S,O,C	S,O,C
Electrical Power I/F and Control	S,O,C	S,O,C
Trouble Shooting Tools	S,C	S,C
Exterior Viewing System Controls	S,O,C	S,O,C
Overall SS Ops Interface	S,O,C	S,O,C
Airlock	S,O,C	S,O,C
EMU, Suits, Headsup Displays	S,O,C	S,O,C
Workbench for Minor Repairs	S,O,C	S,O,C
Data Storage	S,O,C	S,O,C

O = OPERATION  
 C = CONTINGENCY  
 S = SETUP/TEARDOWN/STOW  
 C&W = CONTROL AND WARNING



## INSTRUMENTATION LIST FOR

### TDMX 2561 AND 2562

The instrumentations listed are used for satellite docking and berthing operations and for refueling operations.

All of the instrumentation is assumed to be space station standard equipment that is available for use by these TDMX's.



# INSTRUMENTATION LIST FOR TDMX 2561 & 2562

---

	<u>ITEM</u>	<u>QUANTITY</u>
*	TEMPERATURE TRANSDUCERS	8
*	PRESSURE TRANSDUCERS	3
*	VACUUM TRANSDUCERS	1
*	MASS FLOW METERS	3
*	POWER METERS	1
*	PROXIMITY SENSORS	3
*	VIDEO	2
*	VALVE STATUS	20



## TDMX 2562 SATELLITE MAINTENANCE AND REPAIR

### ● OBJECTIVE

This TDMX, defined on the facing figure, will develop and demonstrate the capability to service free-flying satellites at the Space Station inside an unpressurized hangar. The mission will involve the retrieval of a satellite utilizing the OMV and later, after servicing, return the satellite to its operational orbit. The serviced satellite may be AXAF and will involve the changeout of modules, replenishment of fluids, and spacecraft checkout.

### ● DESCRIPTION

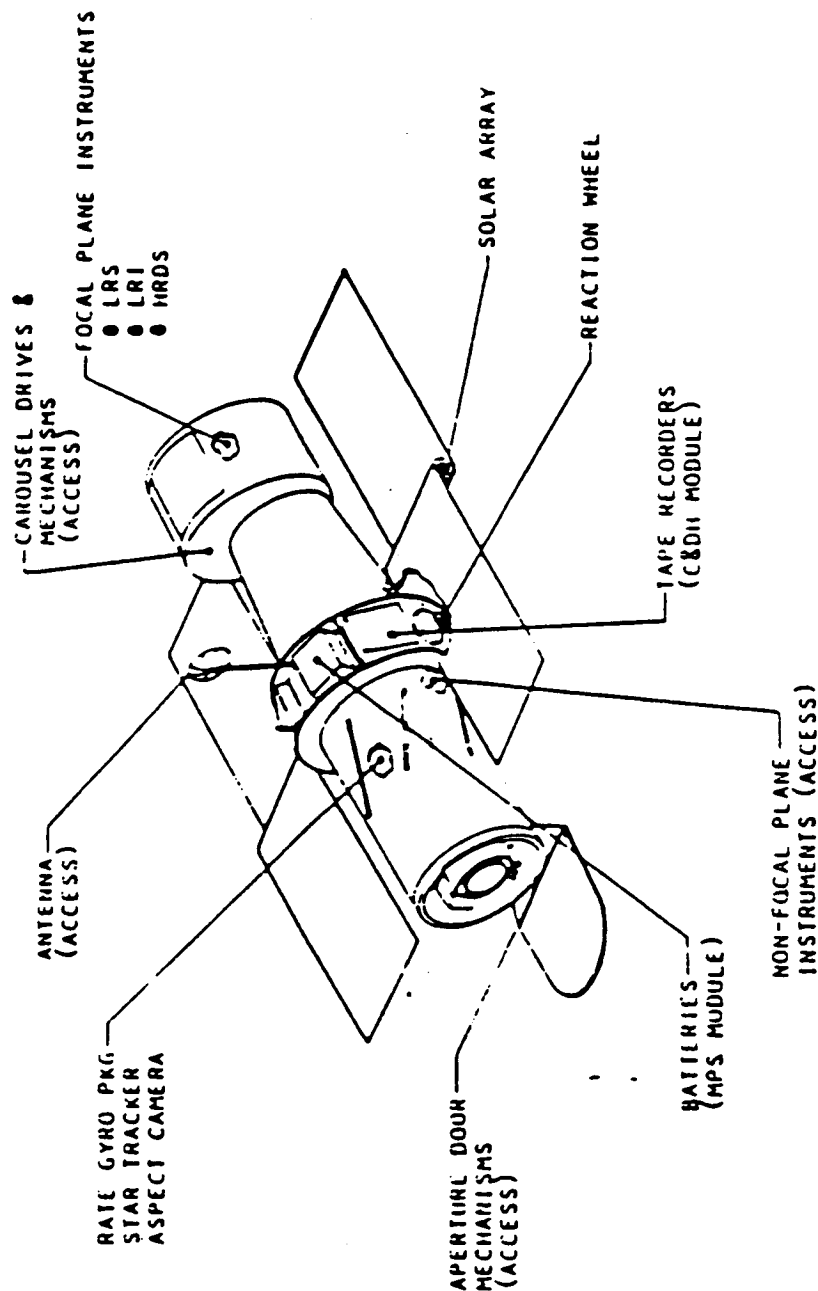
The satellite's replacement modules and fluids are delivered to orbit by the shuttle. The OMV under control of the Space Station will retrieve the satellite from its operational orbit and return it to the Space Station. The satellite will be placed in the servicing hanger by the RMS. Servicing will require both IVA and EVA operations. Astronauts at the service work stations using foot restraints will conduct required service activities: 1) connect servicing umbilicals 2) replace empty gas bottles, 3) replace marginal MMS modules, 4) replace gyro package, 5) evaluate/replace solar panels, 6) power-up satellite, 7) checkout of satellite systems, and 8) perform any additional maintenance. The satellite will then be reconnected to the OMV and delivered to its original or a new operational orbit.



# TDMX 2562 SATELLITE MAINTENANCE AND REPAIR

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- RETRIEVE ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF) FROM LOW EARTH ORBIT, FERRY TO SPACE STATION.
- CONDUCT SERVICING OPERATIONS AT SPACE STATION MAINTENANCE FACILITY --
  - RESUPPLY INSTRUMENT GASES -- REPLACE TANK BOTTLES;
  - REPLACE BATTERIES;
  - REPLACE MPS MODULES (ORUS) -- POWER, ATTITUDE CONTROL SYSTEM, C&DH;
  - REPLACE RATE GYRO PACKAGE (URUS);
  - REPLACE REACTION WHEELS (ORUS);
  - SOLAR ARRAYS -- POSSIBLE ORU REPLACEMENT.
- RETURN AXAF TO OPERATIONAL ORBIT WITH ORV.
- RETURN ORV TO SPACE STATION AND REFURBISH.





## TDMX 2572 CRYOGENIC PROPELLANT

### TRANSFER/STORAGE/RELIQUIFICATION

- OBJECTIVE

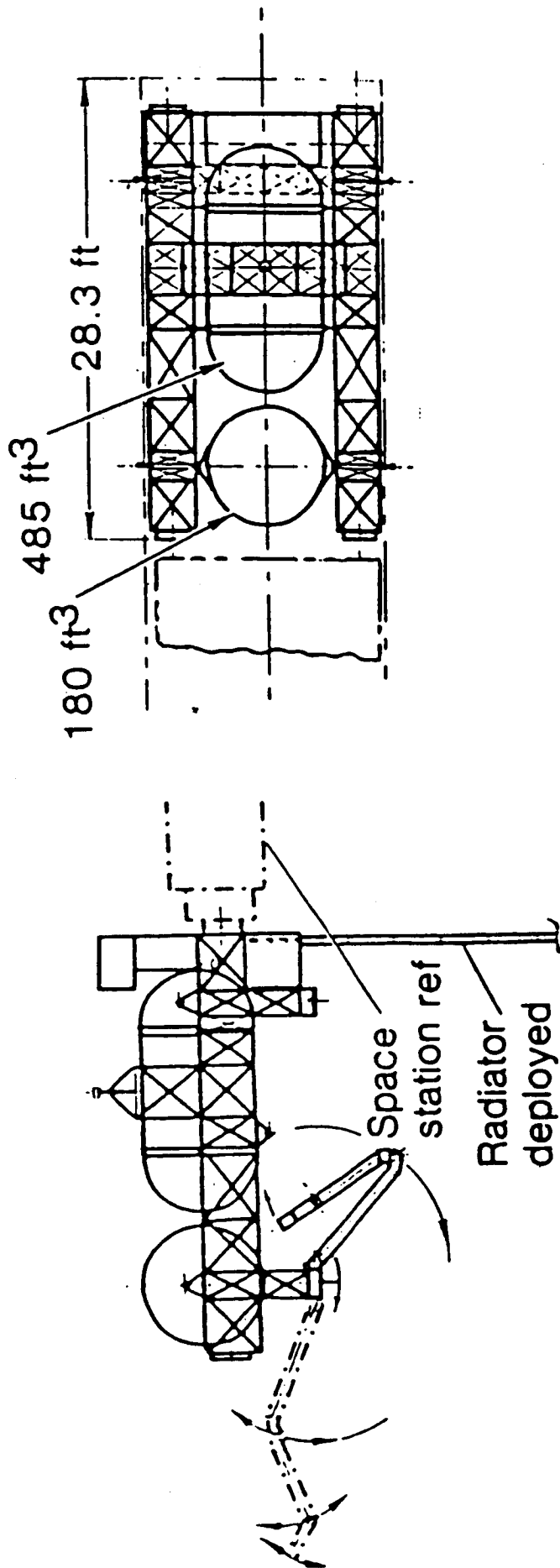
This TDMX, illustrated on the facing page, will develop procedures and hardware for transferring and gauging OTV cryogenic propellants in zero-g and their long duration storage and also for reliquifying the boil-off from the long duration storage tanks.

- DESCRIPTION

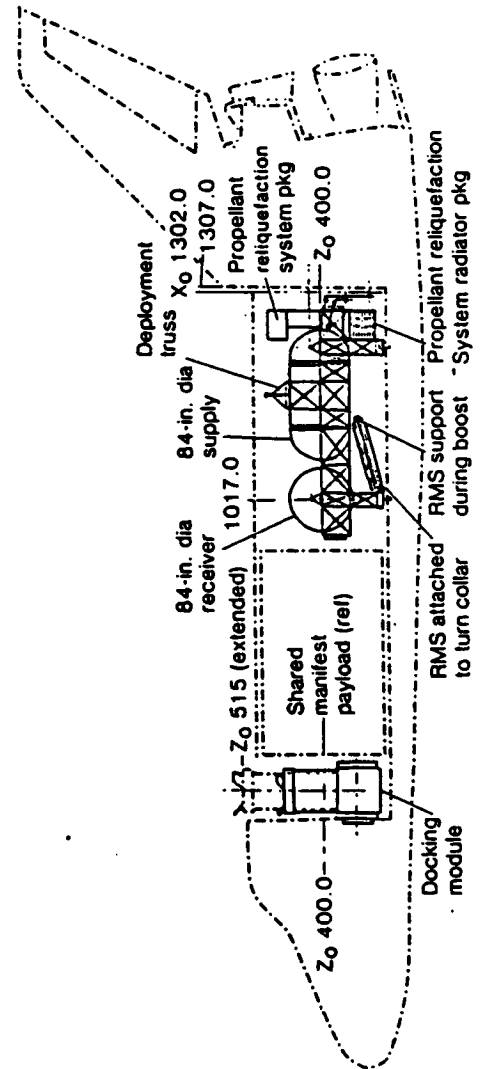
The system consists of supply, receiver and refrigeration components. Propellant transfer is done by using a pump with full screen propellant acquisition device. The supply tank contains subcritical fluid and requires acquisition device for providing liquid to the transfer line. A thermodynamic vent system provides liquid-free venting during storage. Multilayer insulation is required to maintain low incident heat flux to the stored cryogen. A reliquefaction unit is used to reliquify fluid vented from either receiver or supply tank during storage, transfer and chilldown. The resultant liquid is returned to the supply tank.



# TDMX 2572 CYRO PROP TRANSFER/STORAGE/RELIQ



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## EQUIPMENT LIST FOR

### TDMX 2571,, 2572, 2573 AND 2574

This series of TDMX's use a scale version of the OTV to test the capabilities of the space station to service an OTV in orbit. The TDMX will provide all the unique equipment necessary. This will include such items as the mock OTV, berthing port, refueling and servicing facilities. Since this series of TDMX's are meant to test the space station capability, whenever possible existing equipment will be utilized.

This list shows the space station equipment that needs to be reserved when performing this series of TDMX's. The list also shows the time frame during the TDMX's in which the equipment may be used.



# Equipment List for TDMX 2571 - 2574

EQUIPMENT	TDMX 2572	TDMX 2573	TDMX 2574	TDMX 2571
MRMS Controls and Displays	S,C	S,O,C	S,O,C	S,O,C
OMV Controls and Displays		O		
EVA Monitor and Displays	S,S	C	S,O,C	C
C&W Monitor and Displays	O,C	O,C	O,C	O,C
Experiment Monitor and Displays	O	O	O	O
Ground Comm and Displays	S,O,C	S,O,C	S,O,C	S,O,C
Lighting Controls	S,C	S,O,C	S,O,C	S,O,C
Electrical Power I/F and Control	S,O,C	S,O,C	S,O,C	S,O,C
Trouble Shooting Tools	S,C	S,C	S,C	S,C
Exterior Viewing System Controls	S,C	S,O,C	S,O,C	S,O,C
Overall SS Ops Interface	S,O,C	S,O,C	S,O,C	S,O,C
Airlock	S,C	C	S,O,C	C
EMU, Suits, Headsup Displays	S,C	S,C	S,C	S,C
Workbench for Minor Repairs	S,C	S,C	S,C	S,C
Data Storage	S,O,C	S,O,C	S,O,C	S,O,C

O = OPERATION

C = CONTINGENCY

S = SETUP/TEARDOWN/STOW

C&W = CONTROL AND WARNING



## INSTRUMENTATION LIST FOR

### TDMX 2571, 2572, 2573, AND 2574

The instrumentation required for this series of TDMX's will be used to monitor the docking and berthing operations of the mock OTV, the storage, reliquifacating and transfer of fuel and monitor the OTV servicing and payload interfacing operations.



# INSTRUMENTATION LIST FOR TDMX 2571, 2572, 2573 & 2574

---

<u>ITEM</u>	<u>QUANTITY</u>
* TEMPERATURE TRANSDUCERS	8
* PRESSURE TRANSDUCERS	3
* VACUUM TRANSDUCERS	1
* MASS FLOW METERS	3
* POWER METERS	1
* PROXIMITY SENSORS	3
* VIDEO	2
* VALVE STATUS	20
* ACCELEROMETERS	6
* STRAIN GAGES	6
* RF QUANTITY GAGING SYSYTEM	2



## TDMX 2573 OTV DOCKING AND BERTHING

- **OBJECTIVE**

TDMX 2573, as depicted on the following two charts, will provide a technology base for the capability to dock and berth a space-based OTV at a Space Station.

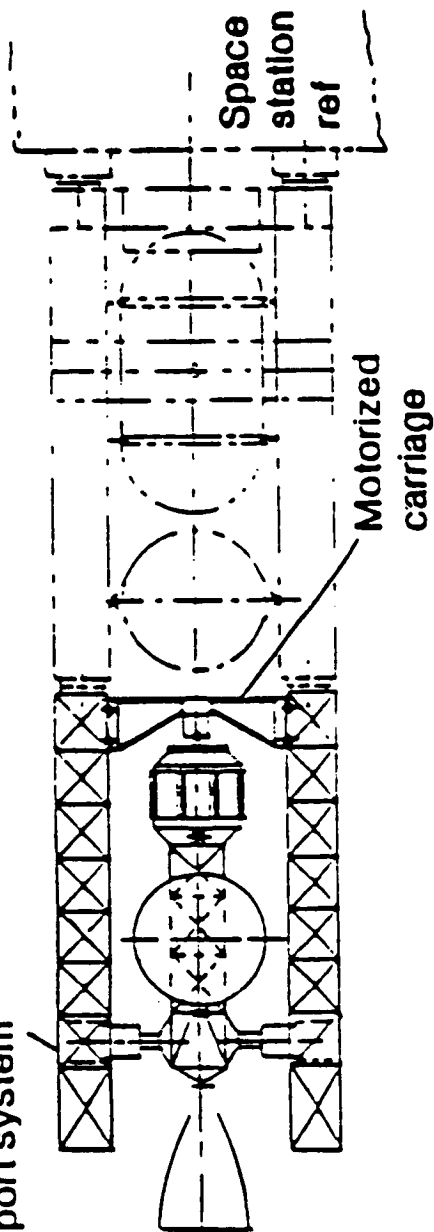
- **DESCRIPTION**

Two basic docking and berthing methods will be examined, depending on OTV configuration capability. One method will incorporate direct docking to the station MRMS, the other method will use an OMV for remote capture of the OTV and RMS handling for berthing operations. There are conceptual designs to accommodate both operations. Plans calls for using the OMV controlling a simulated OTV to implement the docking operations.

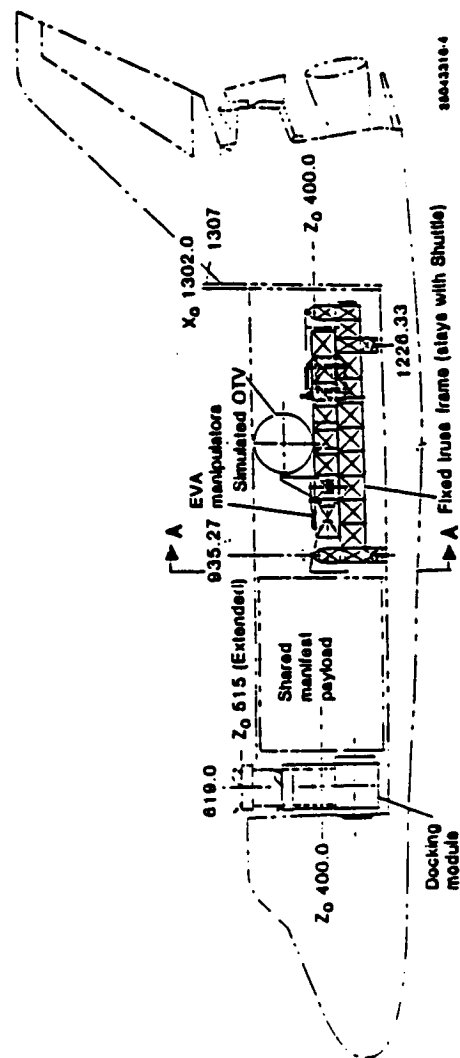
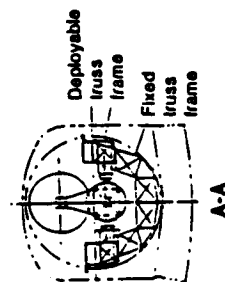


# TDMX 2573 OTV DOCKING AND BERTHING

Berthing/support system



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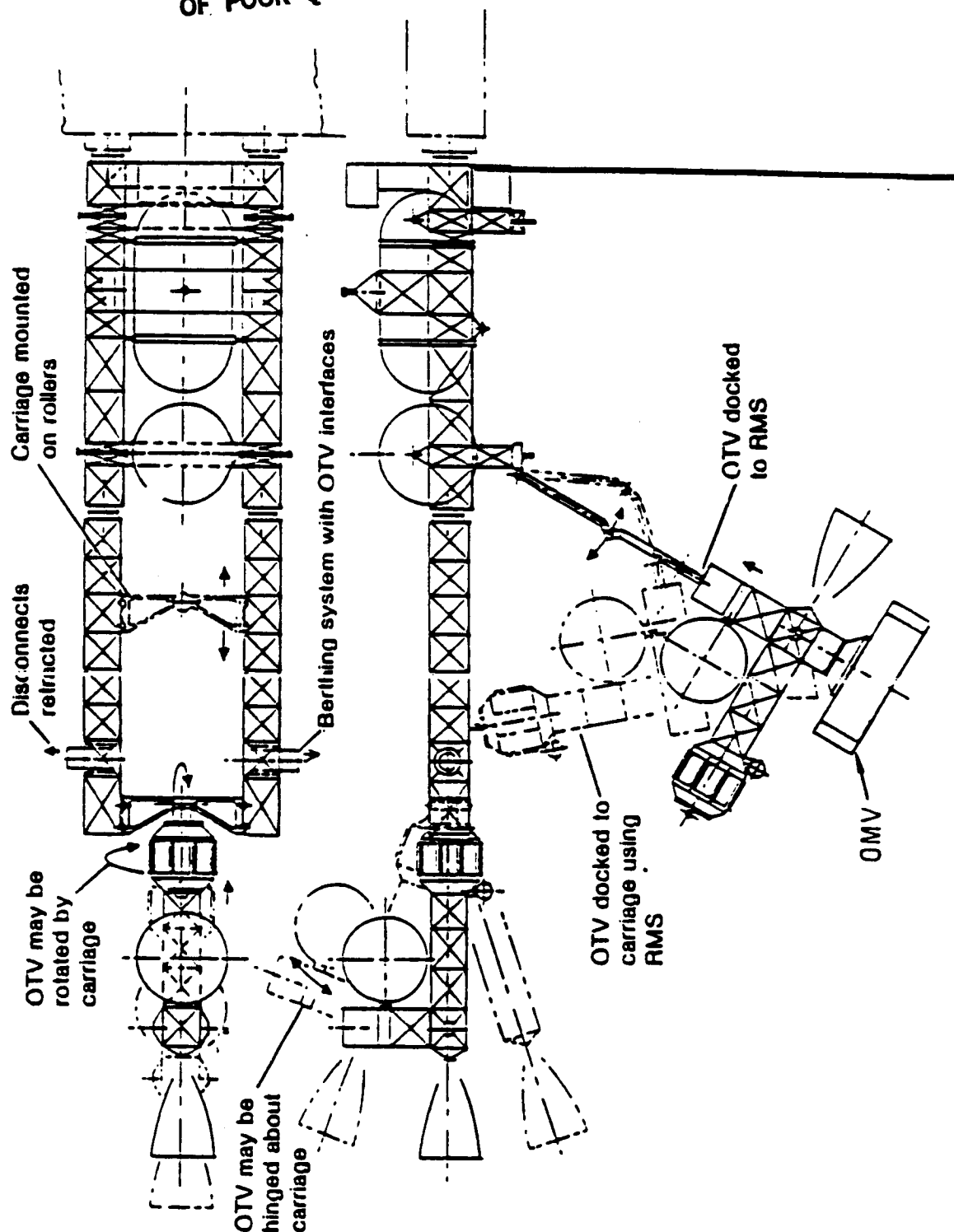


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# TDMX 2573 OTV DOCKING AND BERTHING

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## TDMX 2574 OTV MAINTENANCE TECHNOLOGY

- **OBJECTIVE**

This TDMX, illustrated on the following two charts, will provide a technology base for the development of the capability to recover, maintain, and launch an OTV on orbit. Both automated and EVA maintenance capability will be evaluated.

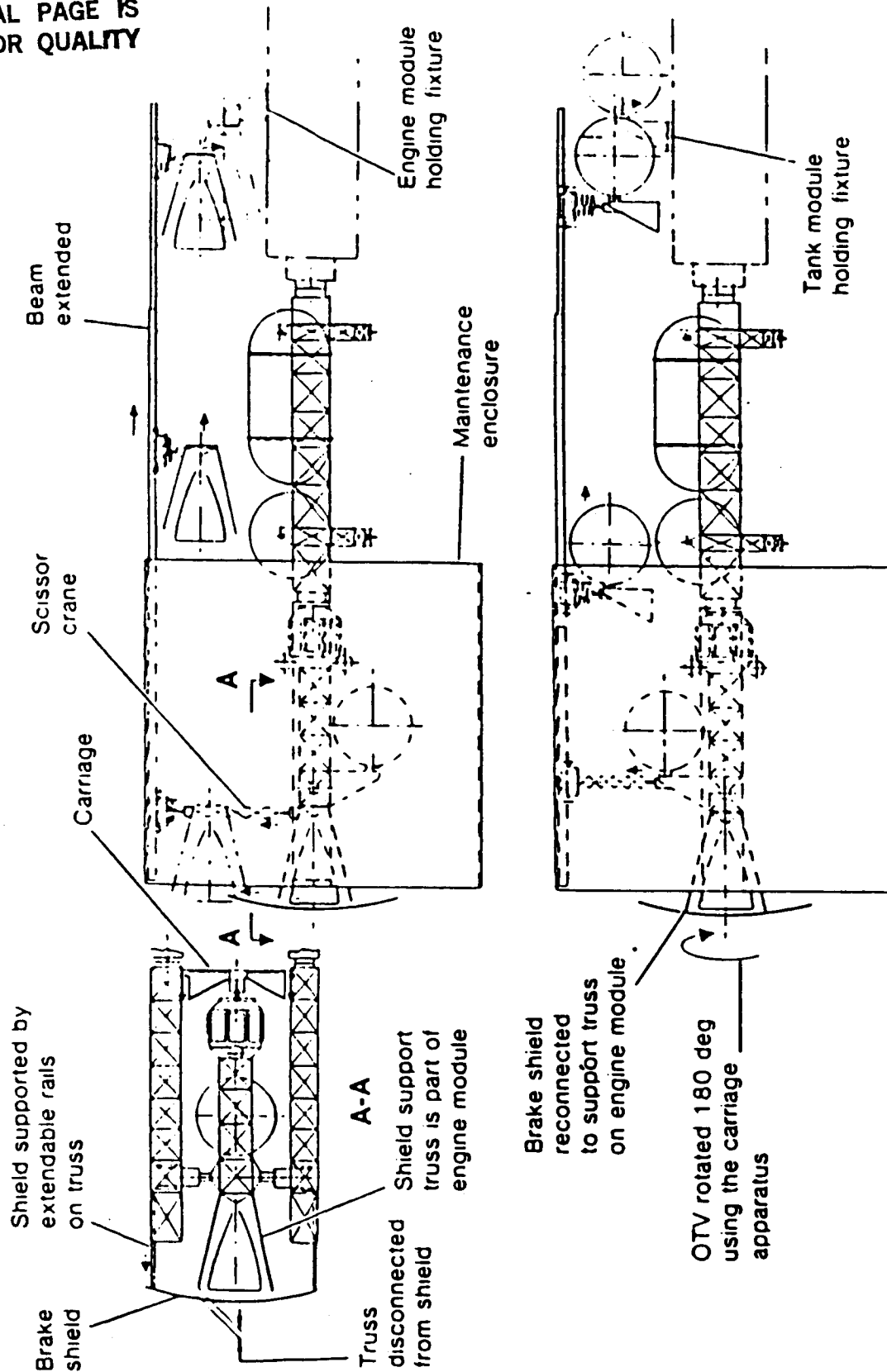
- **DESCRIPTION**

This TDMX will assess the implementations of the following maintenance related functions 1) OTV/Maintenance dock handling: Verify handling operations and maintenance dock equipment compatibility. 2) Service enclosure operations: Demonstrate shelter effectiveness and conduct physical interference evaluation. 3) Visual inspection of OTV components: Verify visual inspection concept and equipment compatibility. 4) OTV component remove and replace operations with remote control arm: Verify adequacy of equipment and evaluate crewman/system interface. 5) OTV component remove and replace operations utilizing EVA: Verify EVA remove and replace equipment concept and equipment compatibility.



# TDMX 2574 OTV MAINTENANCE TECHNOLOGY

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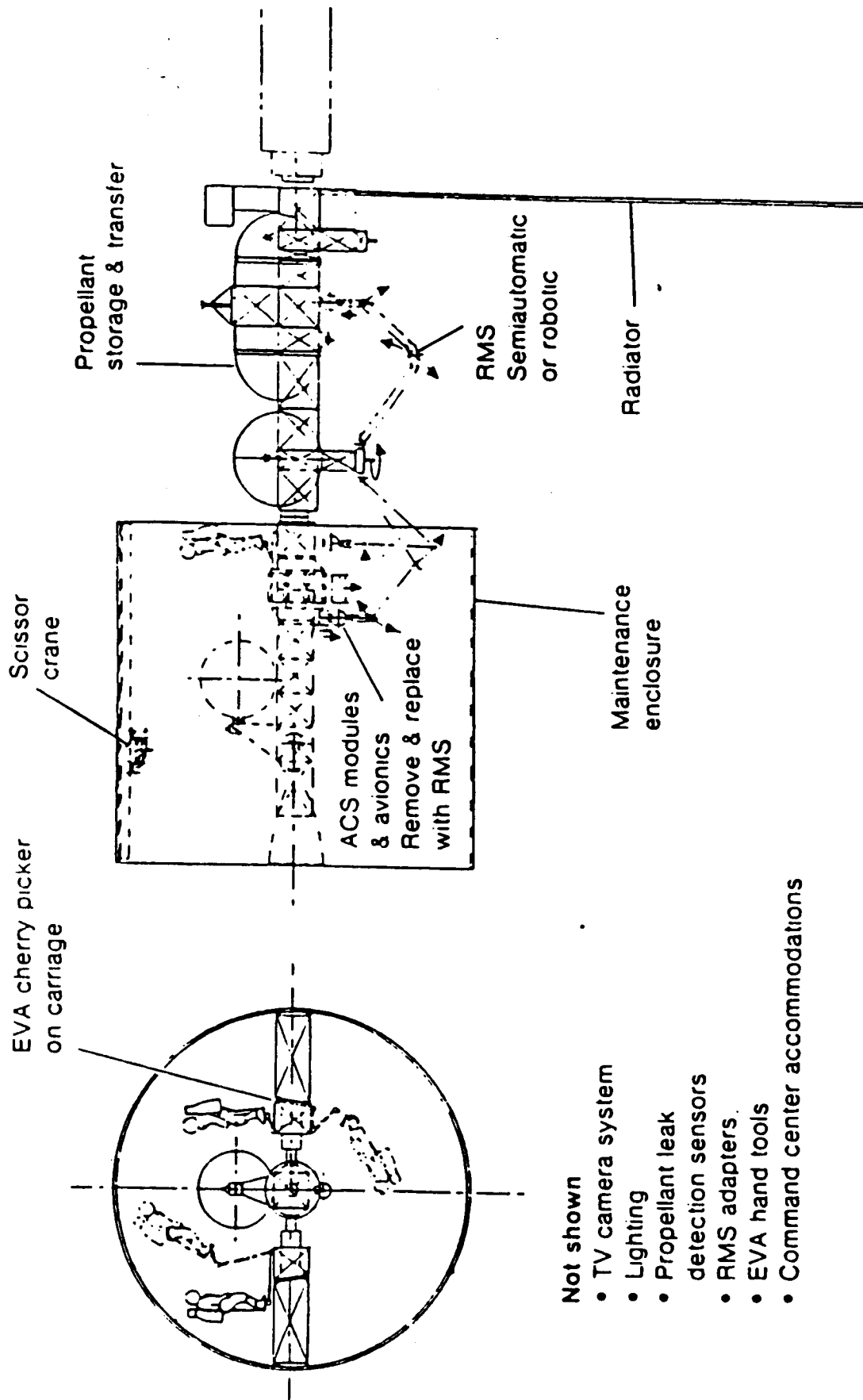




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# TDMX 2574 OTV MAINTENANCE TECHNOLOGY



- Not shown
- TV camera system
  - Lighting
  - Propellant leak detection sensors
  - RMS adapters
  - EVA hand tools
  - Command center accommodations



## TDMX 2571 OTV/PAYLOAD INTERFACING/TRANSFER

- **OBJECTIVE**

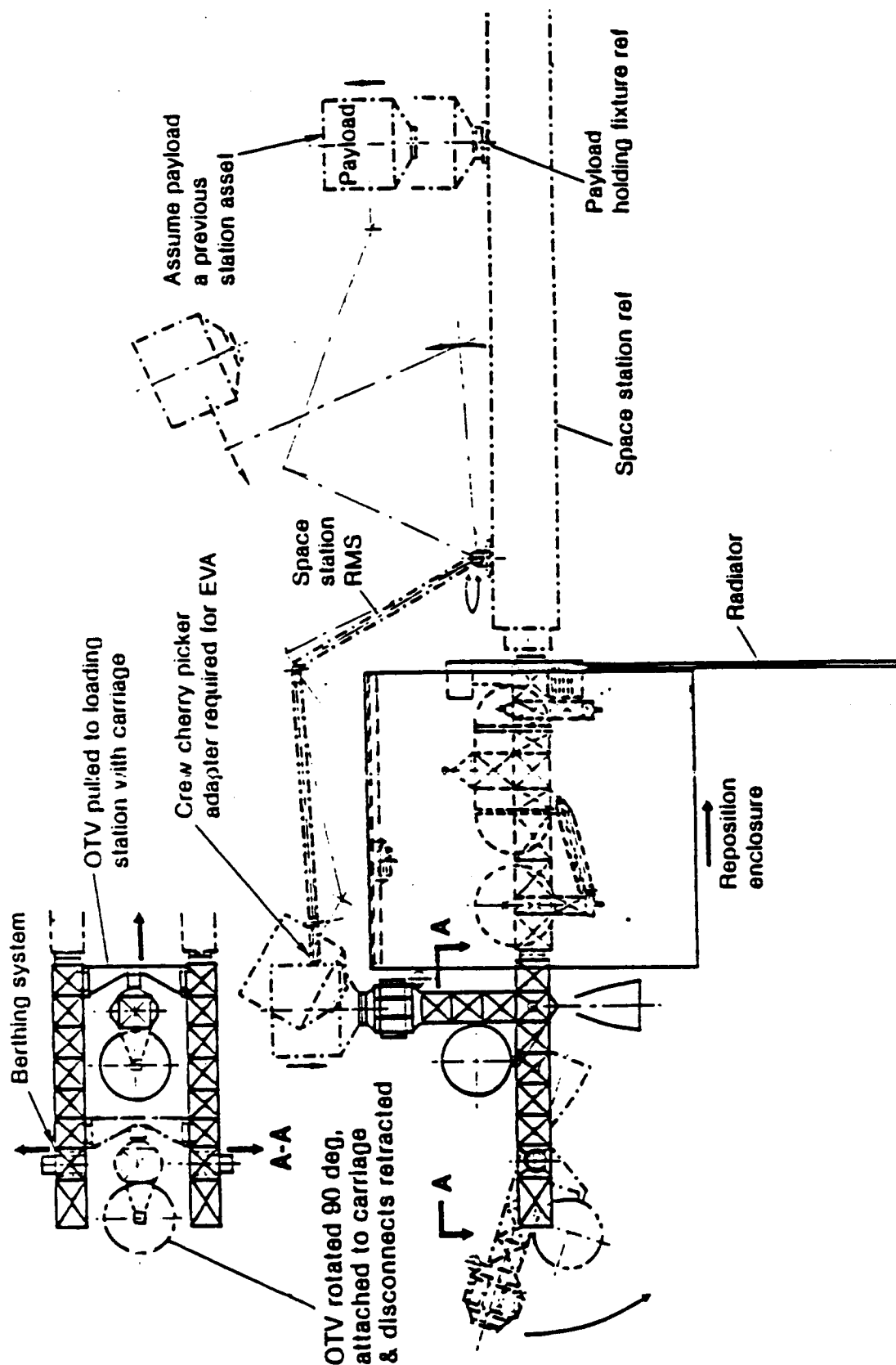
To assess and proof the interfaces, operational planning, and equipment used to perform the operations of handling a payload, mating, and demating the payload with an OTV interface, and performing corrective maintenance on the payload while mated to the OTV. The assessment of the hardware and software adequacy and compatibility under 0 G must be accomplished.

- **DESCRIPTION**

This TDMX makes use of the maintenance, docking, and berthing TDMX equipment, which should already be there. It is also assumed that a simulate payload would be available at the SS. The TDMX personnel and equipment will perform the payload integration tasks outlined in the following timeline to assess the compatibility of the interfaces, operations, and equipment. Timeline (tasks only) - activate facility and rotate OTV, refuel OTV, mate payload to OTV, pre-EVA operations, translate crew to payload perform EVA remove and replace tasks, translate crew to command center, post-EVA operations, demate payload from OTV, mate payload to holding fixture, rotate OTV and deactivate facility.



# TDMX 2571 OTV/PAYLOAD INTERFACING/TRANSFER





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## **SUMMARY**

A study to define the common support and Space Station interface requirements for the Code R endorsed IOC model technology experiments was conducted. The IOC model technology experiments were updated by each principal investigator which included a definition of the experiment instrumentation and data requirements as well as a list of the experiment support requirements. After the identification of the support equipment/hardware requirements for each experiment was completed, a set of common support equipment/hardware was defined. In addition, a preliminary definition of the pressurized laboratory interface requirements was developed. Based on the results of this study, a dedicated technology experiment command and control work station consisting of a command keyboard, cathode ray tube, data storage, television monitor, computer/word processor and an alert/annunciation panel located in a pressurized laboratory will be required to accommodate the technology experiments.

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## **ACKNOWLEDGEMENTS**

The authors would like to acknowledge the outstanding support and input provided by the principal investigators (JPL, LaRC, LeRC, and MSFC) for the IOC model experiments specified for this study. Also, Messrs. Robert Ames, James Brossard, Paul Meyer, and Al Pacheco of the Boeing Aerospace Company are to be commended for their efforts throughout the study. Without the tremendous support of these individuals, and the PI's, the detailed results of this study would not have been accomplished and completed in a timely manner.





## Report Documentation Page

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15. Supplementary Notes Richard A. Russell, Langley Research Center, Hampton, Virginia Richard D. Waiss, Boeing Aerospace Company, Seattle, Washington					
16. Abstract A study was conducted to identify the common support equipment and Space Station interface requirements for the IOC model technology experiments. In particular, each principal investigator for the proposed model technology experiment was contacted and visited for technical understanding and support for the generation of the detailed technical backup data required for completion of this study. Based on the data generated, a strong case can be made for a dedicated technology experiment command and control work station consisting of a command keyboard, cathode ray tube, data processing and storage, and an alert/annunciator panel located in the pressurized laboratory.					
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